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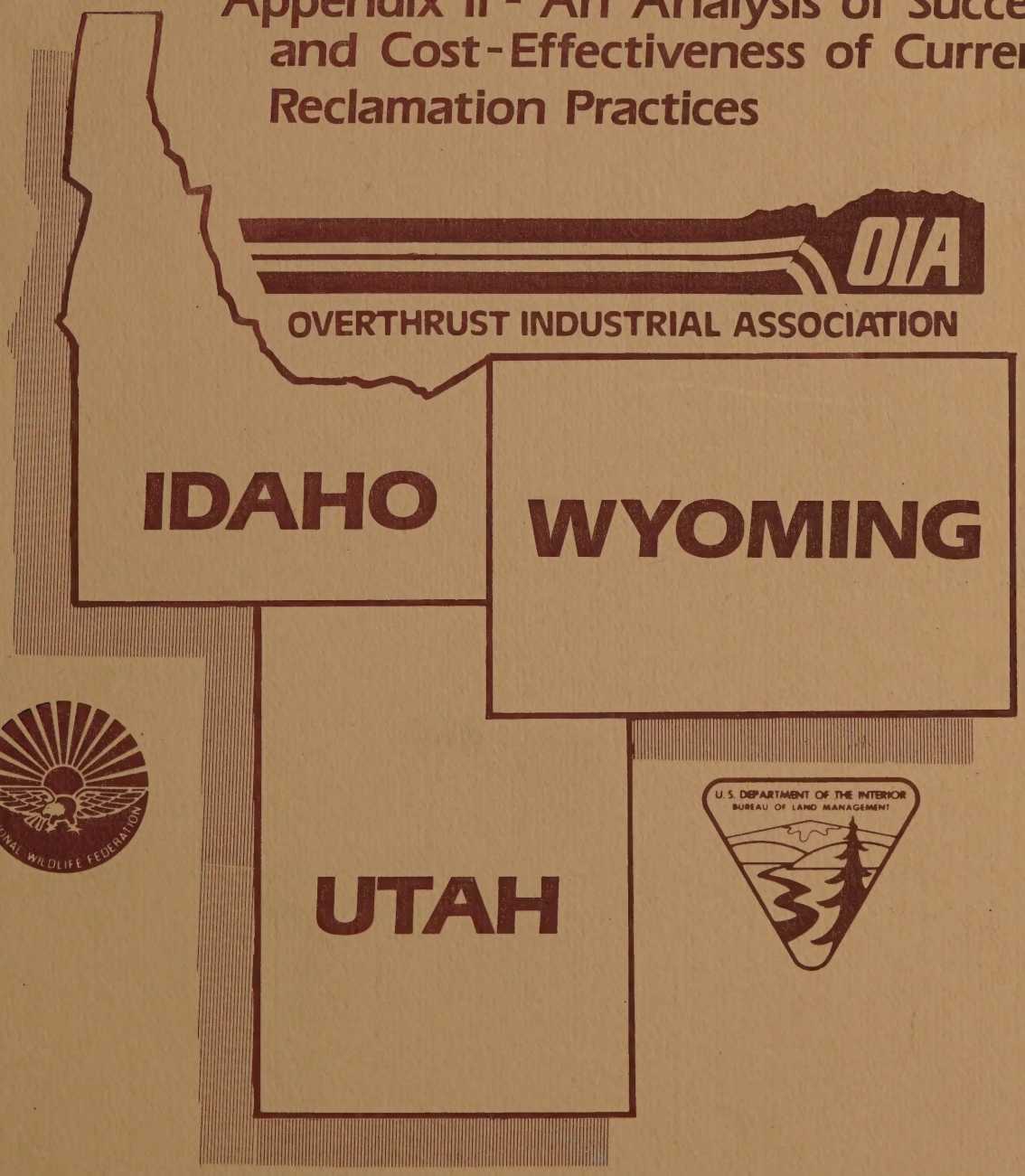
Cooperative Wildlife Program

Appendicies to Reclamation Manual:

Appendix I - A Survey of Existing Literature and Information

Appendix II - An Analysis of Success and Cost-Effectiveness of Current Reclamation Practices



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Appendix I

APPENDIX I: A SURVEY OF EXISTING LITERATURE AND INFORMATION

July, 1985

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This document is one of several developed for the Overthrust Industrial Association's (OIA) Cooperative Wildlife Program. It was prepared by NPI Reclamation Services with primary authorship by Dennis Hansen, Kevin Allred and Kent Ostler.

Significant contributions to this document were made by Dr. E.J. DePuit, especially a draft report on reclamation practices and principles which was used as a framework and basis for the literature review portion of this document.

The Selected Literature References for Rehabilitation of Riparian Habitats was supplied courtesy of Timberline Reclamation, Inc., Bozeman, Montana.

Numerous individuals from government, private industry and public concern groups were contacted, and their comments and suggestions are are included in the report as well as those of the Project Coordinating Committee.

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INTRODUCTION

THE COOPERATIVE WILDLIFE PROGRAM

The Overthrust Industrial Association (OIA) is currently carrying out its Cooperative Wildlife Program, which consists of three elements. These are law enforcement assistance, an environmental awareness training program, and a wildlife management study. The wildlife management study encompasses areas within portions of the Overthrust Belt located in Uinta and Lincoln Counties in Wyoming, Rich and Summit Counties in Utah and Bear Lake County in Idaho. The study consists of three phases.

Phase I has been completed and consisted of a literature search and review, and the design of Phase II. Its objective was to assess the state of current knowledge concerning wildlife resources in the Overthrust Belt in Wyoming, Idaho and Utah, and determine the sufficiency of existing information and analytical methods for understanding, predicting and mitigating the effects of development on wildlife resources. Phase I was conducted by Larry Seeman Associates, Inc. in Berkeley, California and the University of Wyoming in Laramie, Wyoming. Their findings, recommendations for further research, and annotated bibliography are presented elsewhere (Overthrust Industrial Association 1984).

Phase II will consist of collection and analyses of necessary field data from four projects (land reclamation, habitat mapping, sedimentation and mitigation tables) which will result in a set of analytical procedures which can be used to determine accurately the impacts of oil and gas related industrial development upon wildlife. The four projects of Phase II were initiated in the spring of 1984. This report documents the findings from Task I of the land reclamation project of Phase II.

Phase III will include the development of government management recommendations concerning analytical procedures and identification of potentially environmentally sensitive areas, mitigation alternatives and distribution of the final work products. This phase of the study has yet to be initiated.

LAND RECLAMATION OBJECTIVES AND TASKS

Objectives associated with the land reclamation project of Phase II include:

- To determine from agency and accessible company records and personal interviews the success and costs of

reclamation techniques tested and used both in the study area and adjacent areas with similar climatic and physical conditions.

- To determine whether various types of energy development projects had stated reclamation objectives and, accounting for site and contractor's variation, compare the results with the reclamation objectives.

- To evaluate techniques or combinations of techniques in terms of their cost-effectiveness in meeting stated reclamation objectives.

- To compare techniques or combinations of techniques in terms of their relative cost-effectiveness and identify those that are most cost-effective.

- To recommend for testing those techniques found to show promise for cost-effectively accomplishing reclamation objectives.

- To develop a reclamation manual for use in the field.

- To conduct meetings and a workshop with the Project Coordinating Committee of the Cooperative Wildlife Program.

Four tasks and associated subtasks have been identified to achieve these objectives. The task headings are: Task I - Literature Review and Personal Interviews, Task II - Field Assessments and Cost Effectiveness, Task III - Reclamation Manual, and Task IV - Public Workshop and Meetings. This report documents the findings of Task I. Four subtasks were identified for this task:

- Interviews are to be conducted with Project Coordinating Committee (PCC) members and other knowledgeable individuals for information about reclamation practices and their effectiveness, impacts and their mitigation, problems and sources of information.

- A literature search is to be conducted to review and evaluate the applicability of published research describing the types of reclamation techniques used in the Study Area or similar areas in the western United States. The literature review focuses on those

reclamation practices that have potential for use in achieving project goals.

- Reclamation costs are to be catalogued concurrently with the literature review and provided in tabular formats with brief explanations and modifiers for particular circumstances.

- Findings of the first task are to be documented in a written report and presented to the PCC in the first meeting. The report shall be written in a manner that can be used as part of an introductory chapter or appendix for the reclamation manual prepared in Task III.

METHODS AND APPROACHES

Personal Interviews

Personal interviews were conducted with several PCC members and other knowledgeable individuals. Information disclosed during the interview was documented on appropriate documentation of contact forms. Procedures for conducting the personal interviews included:

- Identification of knowledgeable individuals.

- Contact was made with the individuals.

- The reasons for the interview, its format, and ultimate use of the information was explained.

- Permission was requested to cite reference to the interview and/or information disclosed.

- Draft copies of the essential points of discussion were prepared on the appropriate forms.

- A cover letter was enclosed with a draft copy of the interview and sent to the person interviewed for their review. Exception to this procedure occurred when we were referred to someone else or when short communications made it unlikely that information would be misunderstood.

- The cover letter requested that corrections or

clarifications be returned as soon as possible, preferably in writing.

The nature of the questions varied from interview to interview depending on the background of the person being interviewed and their familiarity with sources of information, research being conducted in the area, and reclamation practices. The primary focus of the interview centered on identifying major reclamation problems and concerns, determining personal evaluations of reclamation practices, recommendations for testing or evaluation of new or innovative reclamation practices, identifying reclamation costs, identifying specific reclamation projects in the Overthrust Belt that could be visited to provide a better understanding of problems and effective reclamation practices, and recommendations about other sources of information, research, or knowledgeable people to contact.

It should be pointed out that because of limied time between contract award and preparation of this draft report that it was not possible to make communication with all PCC members and other knowledgeable individuals. Several individuals had commitments that took them away from their offices making contact impossible. It is anticipated that the personal interview process will continue throughout the study and that information will continue to be collected and documented. It is also anticipated that corrections and additions to earlier interviews as reported here will be received later. Documentation of all contacts should be considered preliminary and subject to change pending approval or correction by the person contacted.

Literature Search and Review

Seven major sources of publications and reports were explored for information pertinent to reclamation practices in the Overthrust Belt and adjacent areas. These included: 1) computerized literature databases; 2) College and University libraries in the Rocky Mountain region; 3) USDA Forest Service libraries and publishing offices for the Intermountain Forest and Range Experiment Station and the Rocky Mountain Forest and Range Experiment Station; 4) USDA Forest Service research facilities for the Shrub Research Laboratory in Provo, Utah and the Forest Sciences Laboratory Intermountain Station in Logan, Utah; 5) state and federal agencies in the Rocky Mountain region; 6) personal literature collections of project investigators and other knowledgeable individuals; and 7) literature citations and reports prepared for the Phase I study. A brief description of each major source follows.

A search of several commercial computerized databases was made through the online facilities at the University of Utah. The literature search was restricted to primarily three databases: AGRICOLA, BIOSIS, and Dissertation Abstracts. Selection of keywords included a group of descriptors (i.e. words

or phrases that describe target areas of interest) related to reclamation and revegetation, a group of descriptors related the geographical area to be considered, a group of descriptors related to mining or oil and gas development, and a group of descriptors related to costs and economics. Citations isolated during these searches, covering a period of record from 1976 to 1984 for costs and from 1979 to 1984 for reclamation literature, were printed online at the University of Utah. Citations and abstracts were later reviewed for potential usefulness.

College and University libraries at Utah State University, the University of Utah, Brigham Young University, the University of Wyoming, Idaho State University, and Colorado State University were visited to locate applicable publications, master's theses, and doctorate dissertations.

The USDA Forest Service libraries and publication offices for the Intermountain Forest and Range Experiment Station in Ogden, Utah and the Rocky Mountain Forest and Range Experiment Station in Fort Collins, Colorado were visited to obtain copies of published research reports and bulletins. Bibliographies of individual library holdings for reclamation-related literature were also obtained.

Reports and publications were also collected from the USDA Forest Service Shrub Research Laboratory in Provo, Utah and the Forest Sciences Laboratory in Logan, Utah.

Environmental impact statements, research reports, and copies of published regulations were obtained from state and federal agencies in the states of Utah, Wyoming, and Idaho. Agencies included the Bureau of Land Management,the Forest Service, Utah Division of Oil Gas and Mining, Wyoming Department of Environmental Quality, Wyoming Game and Fish Department, Utah Division of Wildlife Resources, Idaho Department of Fish and Game, and the U.S. Fish and Wildlife Service.

Much of the literature was provided through personal literature collections of project investigators and other knowledgeable individuals. The reclamation library holdings at NPI were extensively used.

Literature and reports prepared for the Phase I study (Overthrust Industrial Association 1984) were used, especially a draft report of reclamation practices and principles by Dr. E.J. Depuit that was only partially incorporated into the Phase I report.

Literature sources were reviewed to determine their applicability to reclamation practices in the Overthrust Belt. Pertinent statements were noted and marked according to general reclamation categories established for the task. These statements and other related information was then evaluated to

determine their potential for use in achieving the project goals.

The original draft report by Dr. Depuit was used as a framework and basis for the more intensive literature review that constituted Task I of this land reclamation study. Dr. Depuit's report was edited, expanded and incorporated into this report where possible in order to utilize the previous efforts that had gone into Phase I without ignoring the report or having to present it as an appendix which might be confusing for the reader.

Reclamation Costs

Reclamation costs were obtained from published sources identified during the literature search and review, from bonding information from state regulatory agencies, and from personal interviews with company personnel and other knowledgeable individuals.

PERSONAL INTERVIEWS

Over twenty-five individuals were contacted and interviewed to determine their concerns about reclamation in the Overthrust Belt. They were asked about practices that they believed were effective or ineffective for reclamation in the study area, sites that could be visited for field assessment, other persons that may be knowledgeable about reclamation in the area, costs of reclamation techniques, and other reclamation-related problems. The concerns and perspectives that were documented during these interviews showed a divergence of opinions regarding the impacts of development on natural resources in the Overthrust Belt and appropriate reclamation techniques that could be used to mitigate any adverse impacts.

Each interview was documented on a written form. Copies of summarized information disclosed during each interview were sent to each individual for their approval and correction to avoid misunderstandings and to ensure the accuracy of the information. Not all of the forms have been returned to date. Until such forms have been verified by the person interviewed all information should be considered preliminary and should not be cited nor copied. Documentation of contact forms are provided in Appendix A.

Despite the divergence of views regarding impacts in the Overthrust Belt and reclamation practices that might best mitigate any adverse impacts, there were several broad concerns that were commonly expressed. These included:

- Problems with erosion and the accompanying loss of topsoil.
- Increased access to the areas and human impacts on wildlife.
- Revegetation using appropriate species that are adapted and palatable to wildlife.
- Control of livestock grazing until vegetation is established initially.
- Planning of pads and roads should be done to reduce any unnecessary vegetation disturbance.
- Mud pits and disposal areas should be designed and reclaimed to avoid contamination of stream habitats.

Other concerns were also raised. Some of which were quite specific and are included in this report. A summary of these concerns follows:

- Over-utilization of newly reseeded areas that may require fencing or transplant protection.
- Stripping and salvaging topsoil including replacement of topsoil as soon as possible.
- Establishing a diverse vegetative cover.
- Seeding should be done in the fall to utilize soil moisture accumulated during the winter.
- Establishment and enforcement of a strong offroad-vehicle policy to eliminate disturbance of reseeded areas.
- Use of cover crops to protect soil from erosion until proper time for revegetation.
- Providing a proper seedbed which included ripping of compacted areas (roads).
- Having biologists involved in the planning and siting of drill pads and road accesses.
- Using of proper reclamation principles.
- Covering of toxic subsoils or proper disposal of drilling muds.
- Use of native species in the revegetation efforts.
- Using techniques such as brush beating (vegetation removal without disturbing the soil or plant roots) to encourage natural regeneration.
- Reducing the time before reclamation occurs.
- Mitigation of disturbance by off-site vegetation enhancement.
- Avoidance of critical areas completely (i.e., riparian zones, critical winter ranges, elk calving areas).
- Regulating access during critical time periods.

- Need to identify reclamation goals and set minimum standards.

These concerns were used to help direct the literature review. A combination of the literature review, personal interviews and the PCC meetings will provide guidance and direction for the field studies that will assess past reclamation practices. Where deficiencies or discrepancies appear to exist, the field studies will attempt to document the best techniques or approaches for the Overthrust Belt study area.

BASIC CONSIDERATIONS

Adequate reclamation of sites disturbed by oil or gas development comprises a major category of impact mitigation. Onsite reclamation is necessary for three types of disturbance associated with oil and gas development: the drill sites themselves, access roads and pipeline corridors. As noted by Box (1978) and the National Academy of Sciences (1974), there are many conceptualized definitions of reclamation. "Restoration" implies an exact duplication of pre-disturbance conditions, and is usually recognized as an unrealistic goal in light of the limitations of current technology. Conversely, "reclamation" usually connotes returning a disturbed site to a similar condition to that which occurred originally. This latter, more feasible concept of reclamation will be utilized in this report. Reclamation might thus be defined broadly as the process of returning a disturbed site to a condition approximately equal to or better than that prior to disturbance in terms of sustained support of function, physical processes, biological organisms and land uses.

Successful reclamation is predicated both on an integrated, whole-system approach and on properly ordered organized applied practices. Wali (1975) noted the essentiality of a holistic systems approach in cases where reclamation strives to reestablish entire functioning ecosystems on disturbed lands. Ecosystem reestablishment and function on disturbed lands is dependent upon both recognizing and addressing all biotic and abiotic components of the system and their interrelationships. A short-sighted approach to reclamation stressing only a limited array of ecosystem components, for example, emphasis on revegetation and/or wildlife alone, may obviously often overlook other critically important factors and result in failure. In short, an integrated, multidisciplinary approach to reclamation is mandatory, requiring input from such varied fields as geology, hydrology, soil science, botany, zoology, agronomy, and natural resource management, including wildlife--all in an ecological context.

To be successful, the entire-system approach to reclamation described above must ultimately yield a properly designed and organized sequence of applied reclamation practices for any given disturbed site. Reclamation should be approached as an ordered process, and may be conceptualized as having three sequential stages, or "phases": a predisturbance planning phase, an implementation phase, and a management and monitoring phase. A brief discussion of each follows.

PREDISTURBANCE PLANNING PHASE

As its name suggests, the predisturbance planning phase represents reclamation activities conducted prior to disturbance. As discussed by Riddle and Saperstein (1978), preplanning is essential to potentially successful reclamation, and includes such activities as:

- Baseline studies (biotic and abiotic) to characterize the predisturbance environment.
- Identification of potential impacts of development on the environment.
- Identification of reclamation goals for mitigation of the impacts.
- Identification of specific reclamation problems.
- Development of a specific reclamation plan (i.e., applied methods) to overcome problems and, thereby, achieve goals.

IMPLEMENTATION PHASE

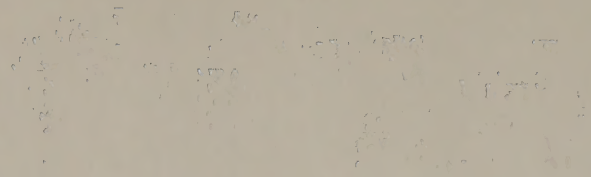
The implementation phase of reclamation represents the subsequent actual application following disturbance of the detailed reclamation plan derived during the preplanning phase. If the preplanning phase activities have been carefully approached and adequately developed, then the logistics of the implementation phase are greatly facilitated. Without the proper level and quality of planning, the implementation activities may fail to achieve the proper results. Specific operational objectives and plans for the project should be prepared for each phase of the operation. When drafting these plans, careful consideration should be given to all alternative reclamation practices with respect to effectiveness in meeting reclamation and land use objectives, environmental effects, cost and operational efficiency, whether the project can be effectively handled "inhouse" or if the services of an outside contractor are required, equipment needs and selection, scheduling considerations, and estimates of costs for each phase of the project (Harwood 1979). Contingency planning is especially useful in facilitating activities during the implementation phase.

MANAGEMENT AND MONITORING PHASE

The management and monitoring phase of reclamation commences after initial field application of reclamation (i.e., the implementation phase) has been completed. Environmental monitoring serves a dual function: it provides data on the success and/or short comings of initially applied reclamation practices, which are useful both in terms of regulatory evaluation and for design of necessary management practices on the site. As noted by Packer and Aldon (1978), proper management during and after initially applied reclamation practices is extremely important to the ultimate achievement of reclamation goals; without it, benefits of proper predisturbance planning and implementation may be largely negated. It is important to realize that immediate achievement of reclamation goals on drastically disturbed lands will rarely, if ever, be possible. Initially treated disturbed lands may be expected to change with time as plant and animal community succession and soil development proceed (Sindelar 1978). Management practices are employed to properly direct and, if possible accelerate this process of change, and may have one or more of the following functions:

- Corrective - to alleviate flaws or short comings in initially applied reclamation practices.
- Protective - to temporarily shield the site from deleterious outside influences.
- Manipulative - to direct plant/animal community and soil system changes toward a desired future condition over time.

Because wildlife populations are generally limited by habitat availability, disturbed land reclamation for wildlife generally involves reestablishment of requisite physical and biological features of habitat (Plummer et al. 1968, Harju 1980). As noted by Frischknecht (1978), the extent and facility that man can exert in manipulating the various factors comprising wildlife habitat via reclamation will determine the rate of recovery of disturbed lands for support of wildlife. Unfortunately, development of reclamation technology specifically for wildlife habitat reestablishment has progressed at a slower rate than that for other land uses. Further, while habitat reclamation has been addressed through a number of western regional symposia and reports (e.g., Ecology Consultants, Inc. 1978; Institute for Land Rehabilitation 1978; Swanson 1979; Hinkle et al. 1981; Thorne Ecological Institute 1982), very little (if any) information has been published with specific pertinence to the Overthrust Belt Region. The following sections on reclamation practices will therefore by necessity draw heavily upon potential practices for the region as extrapolated from established technology for nearby areas; the absolute applicability of such



practices to the Overthrust region will obviously remain to be verified by field research and implementation. Reclamation technology will be presented within the framework of the three ordered phases and in line with the general considerations for reclamation discussed above. Although wildlife habitat considerations will be emphasized, the holistic, multidisciplinary approach essential to reclamation will be maintained.

CURRENT RECLAMATION RESEARCH AND PRACTICES

Reclamation of petroleum development-related land disturbances in the Overthrust Belt is a relatively recent concern. While some progress has been made by the petroleum industry in development of reclamation technology, little research has been completed and reported. Because of a lack of published information on reclamation practices specifically associated with petroleum development disturbances within the Beaver River Divide/Overthrust Belt study area, the following brief generalizations on current reclamation practices in the area are based upon direct consultations with industry reclamation personnel and upon findings as documented in the Phase I report (Overthrust Industrial Association 1984). Except where noted otherwise, practices discussed will apply to all three types of disturbed land (i.e., drill sites, access roads and pipeline corridors).

CURRENT RESEARCH

Most research conducted within the study area to date has focused on evaluating techniques and practices for reclaiming disturbances associated with the mining of phosphate or coal. Results of this research are generally documented in various formats in unpublished company files. Mining companies conducting such research include: Chevron U.S.A. Inc.'s Vernal Phosphate mine (research conducted by NPI and the Utah Division of Wildlife Resources), Monsanto's Henry Mine in Idaho and the Kemmerer Coal mine near Kemmerer, Wyoming. Concern for wildlife impacts from phosphate mining in the Overthrust Belt has resulted in a major "Cooperative Wildlife-Phosphate Study." The study's summary and management recommendations for reclamation were published by the Idaho Department of Fish and Game (Kuck 1984). An environmental assessment has been prepared for oil and gas development on Forest Service land in the Mt. View, Evanston and Kamas Ranger Districts (USDA Forest Service 1981). Another major research effort is being conducted at Pittsburg and Midway Coal Mining Co.'s Kemmerer Mine. It is funded by the National Science Foundation and focuses on the reconstruction of ecosystems in arid lands. Its objectives, according to Dr. James A. MacMahon of Utah State University, its principal investigator, will be testing a number of ecological hypotheses, particularly regarding succession, and developing methods of projecting the consequences of different management alternatives. An interdisciplinary team of physical, biological, and systems scientists at Utah State University are involved with the study. Revegetation plots were all initiated in the fall of 1981. A progress report for 1982 has been submitted, however, the 1983 progress report has not been released yet.

A third major study in the Overthrust Belt was one funded by the U.S.D.A.

Forest Service, under the direction of Mr. Bland Richardson at the Forestry Sciences Laboratory in Logan, Utah. The principal investigator was Dr. E. J. Depuit at the University of Wyoming. The objective of the study was to evaluate plant community successional status on a series of abandoned oil or gas exploratory drilling sites occupying both sagebrush and coniferous vegetation types within the Bridger-Teton National Forest. Sites ranged from 3 to 33 years in age since abandonment. Some of the sites received reclamation treatments at the time of abandonment, while others revegetated naturally. Although the final report has not yet been completed, a master's thesis was published at the University of Wyoming (Waldvogel 1984), documenting many aspects of the study. Recommendations are given for practices and species that showed promise for reclamation of drilling sites (Appendix C).

Miscellaneous research is currently being conducted and evaluated by Chevron and Amoco, although, no findings have been reported to date (e.g., testplot work conducted at the Anchutz Ranch by NPI for Amoco). Much useful information and practical experience has also been generated by industry reclamation scientists from experimentation and observations made while actually implementing reclamation practices.

CURRENT PRACTICES

Current reclamation practices in the Overthrust Belt are documented in Appendix E of the Phase I report (Overthrust Industrial Association 1984). The appendix presents descriptions of various reclamation practices used by mining companies and the oil and gas industry in Wyoming, Idaho, and Utah. Twenty-two individuals were interviewed by telephone to assess approaches used in reclamation, revegetation, and wildlife habitat manipulation. Included in the interview were questions directed at practices of topsoil stockpiling, topsoil/subsoil separation, recontouring slopes and reapplied soils, slope stabilization, mulching and other soil stabilization measures, seedbed preparation and seeding practices, methods used for shrub establishment, and the use of fertilizers and irrigation. A brief literature review of reclamation practices is also included in the report. Portions of their literature review have been incorporated into this report where applicable.

In most cases, some effort is made by the petroleum industry to salvage and stockpile topsoil prior to site development for eventual redeposition as an improved plant growth medium, recognizing that topsoil resources are usually of limited quantity and sometimes of poor quality in the study area. Much variation in regrading procedures apparently exists among operators. Many operators strive to return a disturbed site to approximate original contour, while others grade to as level a topography as possible.

Ripping of subsoil is sometimes accomplished following regrading to relieve compaction, but this practices is not universal. Following regrading, topsoil is respread and, in some cases, is ripped or chisel plowed to alleviate compaction.

A number of methods are sometimes employed to initially stabilize and/or conserve moisture on regraded, topsoiled sites. Water diversion bars are frequently constructed on access roads and pipeline corridor sites to reduce water erosion. Department of the Interior guidelines are generally recommended as standards for minimum design specifications for roads, fences, cattleguards, water crossings, culverts, waterbars, terraces, and other erosion control techniques (USDI 1978). Various organic mulching methods are sometimes implemented, although their use is not universal. A few operators have achieved good results by planting cover crops to produce stubble mulch as an approach to site stabilization.

Selection of plant species for permanent revegetation is sometimes made by industry personnel, but more often, on public lands at least, is based upon suggestions or requirements of regulatory agencies. Bureau of Land Management recommendations in the Kemmerer, Wyoming District Office prior to 1980 included a diverse seed mixture with several species of forbs and shrubs; since 1980, the BLM out of the Kemmerer office has recommended a seed mixture with fewer species, predominantly grasses. The current emphasis in the Overthrust Belt is on native species (primarily grasses and secondarily shrubs) which are adapted to site conditions. Most revegetation is accomplished by direct seeding methods; little or no transplanting occurs. Drill seeding methods, when feasible, are nearly always employed, and seeding is generally conducted in either fall or spring. Fertilization is conducted in certain cases, although the benefits of such are frequently challenged. Irrigation, for logistical reasons, is generally not used. Specialized management of reseeded areas, such as site protection from livestock is only rarely implemented.

As is evident from the preceding paragraphs, much variation exists among operators in terms of both specific practices and level of reclamation technology employed. In short, recognized "standard" reclamation procedures have not yet been developed, proven and accepted, which subsequently might be appropriately modified to address site-specific conditions at any given disturbance. Reclamation success apparently has also been varied, perhaps corresponding to differences in methods employed as well as to differences in site-specific conditions or annual climatic fluctuations.

Thus, although some progress has been and continues to be made in-house by the petroleum industry, reclamation technology is currently still in an early stage of development within the Bear River Divide/Overthrust Belt region. Major problems related to the harsh edaphic/climatic regime of the

area remain to be adequately solved, such as limited soil quality and quantity, erosion control and water availability and conservation. Feasible and cost-effective management practices to protect and/or manipulate initially reclaimed sites comprise another recognized need. Multiple use reclamation strategies remain to be comprehensively addressed; for example, requisites for the wildlife component of multiple use have often received inadequate consideration in reclamation activities to date. Resolution of problems such as these will depend upon two factors. First, an increased recognition of the priority of and commitment to reclamation by the petroleum industry is essential; progress in meeting this requisite is currently being made. Second, improved reclamation methods require development, through research and application, which are specifically applicable to petroleum development-related disturbances in the immediate study area. Fortunately, considerable progress has been made in reclamation technology for other types of disturbances in regions adjacent or similar to the Overthrust Belt; much of this technology may be directly or indirectly applicable, following field testing, to the Overthrust Belt area. The following pages will summarize reclamation practices developed elsewhere which might potentially be utilized or modified to enhance onsite reclamation in the study area, emphasizing wildlife considerations.

PREDISTURBANCE PLANNING PHASE--POTENTIAL RECLAMATION PRACTICES

As noted previously, adequate onsite reclamation for wildlife and other land uses is as dependent on proper planning before site disturbance as on subsequent implementation and ultimate management. Hinkle et al. (1981) and Moore and Mills (1977) have described the specific predisturbance activities discussed below as necessary in formulation of wildlife reclamation programs for surface mined lands in the West. It is felt that a similar approach may have utility, if appropriately modified, for reclamation of petroleum development-related disturbance in the Bear River Divide/Overthrust Belt area. The information gathered in Phase I and II of the OIA's Cooperative Wildlife Program can be used as a source for providing much of the information necessary for the following activities. Thus, many of these activities can be accomplished relatively quickly . Each manager should extract applicable information and procedures for their site specific situations. Specific predisturbance activities include:

- Describing baseline resources.
- Analyzing impacts.
- Establishing reclamation/land use objectives.
- Developing a reclamation plan to mitigate impacts and achieve objectives.

These activities provide for the development of a sound inventory of the natural resources and the environmental and ecological factors affecting these resources. Extensive preplanning should be done to understand and classify site conditions and variables because success is conditioned by a host of factors that are often site specific (Packer 1974). Stevens et al. (1974) developed a system for assessing site potential by relating the edaphic, topographic and precipitation variables that influence plant growth.

According to Merkel and Currier (1973), some information useful in making land use decisions includes, but is not limited to the following: land ownership; hydrology; land use zoning; past and current management practices; kinds, extent and severity of existing land problems and their causes; managing agencies involved; present biotic uses; climatic data; land form data; geology and soils information; kinds, types and extent of vegetation present; general public factors to be considered, such as safety, aesthetics, and recreational possibilities; land and cultural improvement, present and needed; kinds and extent of land, water and air pollutants; possible legal problems present and anticipated; land legislation that may be needed, etc.

The following are some objectives of the predisturbance planning phase which should be considered before decisions are made:

- To identify all current resources.
- To identify the environmental and ecological factors affecting the resources.
- To identify the type of use being made of the resources.
- To identify past and present management practices and their effectiveness or ineffectiveness.
- To identify the present factors affecting the land owner's or manager's concern about present and planned land practices and management.

Sources of such information may be readily available from the Phase I and II reports or from other companies, government agencies, land owners, or consultants familiar with the area. The level of detail required for each category of information will vary with site conditions, magnitude of disturbance, timing of activities, and other factors.

DESCRIBING BASELINE RESOURCES

Baseline studies are designed to provide a comprehensive description of physical, floral and faunal resources of an area to be disturbed, as well as information on the specific nature of the disturbance itself. Such information is necessary for three basic reasons:

- To define potential impacts.
- To define potential problems in impact mitigation.
- To provide a resource data base which allows formulation of reclamation objectives and methods, and which provides a means of subsequent evaluation of reclamation success.

Baseline studies should first assemble information on the nature of the proposed development. In the case of petroleum development, such information as location, number and arrangement of potential drill sites, access roads,

pipeline corridors, and ancillary facilities; scheduling considerations; development activities; and other related types of information should be assembled. Baseline environmental information on climate, physiography, hydrology, soils, vegetation and land use, and the interrelationship of such in ecosystem function, is essential for general reclamation planning.

Information assembled during the baseline assessment will be useful in directing subsequent reclamation efforts (Merkel and Currier 1973). For example, information on the vegetation may be useful in indicating which species of vegetation might be best suited for the site; or it might indicate correlation with adverse climatic conditions such as excessive snowdrift accumulation. The nature of the soil may determine its ability to function as a growth medium; if good soil material is sparse it might suggest a need for salvaging and stockpiling topsoil; other soil parameters such as its physical and chemical nature might dictate the types of species that will be best suited to the altered site, and its potential for erosion. Climatic information may help in assessing the need for specialized reclamation techniques such as adequate protection from the wind and mulching requirements. Biotic factors such as livestock, wildlife, rodents, and insects may be important to know so that proper control measures may be planned. For example, hay mulches may attract wildlife in some areas and the use of artificial mulches may improve revegetation success. Knowing that unusually heavy grazing pressures might occur in the area might be important when selecting species that might tolerate such pressures. In summary, the baseline information is useful in many ways when developing the reclamation plan.

Survey and sampling techniques for collecting such data on potentially disturbed lands have been developed for the mining industry (e.g., Cook and Bonham 1977; Barrett et al. 1979; USDA Forest Service 1979; and others) which could be modified for use by the petroleum industry. Petroleum development disturbances are small but numerous, and can hence be expected to impact, either directly or indirectly, surrounding lands as well as the immediate drill site, access road or pipeline sites themselves. Therefore, area-wide baseline surveys on the environmental parameters listed above may be appropriate.

ANALYZING IMPACTS

Baseline wildlife studies are obviously of critical importance if reestablishment, maintenance and/or enhancement of wildlife land use are desired following reclamation. One of the objectives of the Phase I Literature Survey (Overthrust Industrial Association 1984) was to define

potential impacts of industry development on wildlife and to identify potential mitigation. Information developed during the Phase I study, and subsequent efforts to identify impacts and their mitigation, are especially useful when developing an effective reclamation plan. Hinkle et al. (1981) and Moore and Mills (1977) included the following as essential components of wildlife studies on potentially disturbed lands:

1) Defining and evaluating the zone of potential influence or impact, both direct and indirect, of proposed development activities or land disturbances on wildlife

2) Within the zone of potential influence:

   a). Inventorying Wildlife Species, including information on wildlife species presence, approximate abundance and distribution, movement patterns and habitat requirements--particularly for species of defined major ecological and/or economic "importance" (e.g., game species; rare, threatened and/or endangered species; etc.).

   b). Inventorying Wildlife Habitat, including information on the distribution and biophysical characteristics of habitat types, nature of utilization of habitat types by "important" wildlife species, unique features of habitat types, distribution and nature of critical habitat types.

   c). Determining Wildlife Species/Habitat Value, including information relevant to an evaluation of the relative importance ("value") of wildlife species for area land use and/or of area habitat characteristics for wildlife use.

Both Hinkle et al. (1981) and Moore and Mills (1977) provide reviews of wildlife baseline study procedures for potentially disturbed lands.

ESTABLISHING RECLAMATION AND LAND USE OBJECTIVES

Results of baseline studies are of obvious importance in defining probable, possible and/or unlikely impacts of disturbance on wildlife and other land resources. Once potential impacts have been defined, reclamation goals may be established which will determine the manner and degree of

specific impact mitigation necessary. The nature of reclamation goals for any particular impacted area depends on which of the following three land use scenarios is judged most beneficial:

- Single use - i.e., area is to be reclaimed for only one type or class of land use.
- Prioritized multiple uses - i.e., multiple land use with a certain use or uses of higher "importance" than others.
- Non-prioritized multiple uses - i.e., multiple land use with all major uses of roughly equal "importance".

In practice, the latter two land use scenarios are most likely to influence reclamation goal determination over most of the Bear River Divide/Overthrust Belt region. Hence, wildlife reclamation goals will usually be accompanied by goals for other, concurrent land uses. If wildlife is judged especially "important" in a given area, broad reclamation goals may include either maintenance or enhancement of predisturbance habitat features under the prioritized multiple use scenario. The reverse may hold true under the prioritized multiple use scenario if other land uses are judged more "important" than wildlife. If all predisturbance land uses, including wildlife, are considered of equal value, the broad postdisturbance reclamation goal will probably be for nonprioritized multiple uses - implying maintenance of predisturbance habitat conditions for wildlife.

If wildlife use of an area is judged of equal or greater value to other land uses, reclamation goals will usually involve ultimate provision of either maintained or improved specific habitat features required for one or more ecologically or economically important, key wildlife species. If such habitat features are successfully reestablished, it is assumed that desired populations of key wildlife species will ultimately be redevelopable.

DEVELOPING A RECLAMATION PLAN

Once baseline studies have been completed, potential impacts have been defined and reclamation goals have been set, reclamation planning can commence. As noted by Moore and Mills (1977), reclamation planning should yield a properly ordered, integrated sequence of methods to address all

aspects of ecosystem reestablishment on disturbed areas, and may, in the case of wildlife, include techniques for the enhancement of offsite habitat features. Specific reclamation methods, such as those discussed in detail under the implementation phase of reclamation, should be carefully planned in advance to assure proper scheduling of activities, efficient and cost-effective reclamation operations, and ultimate achievement of desired site conditions.

With regard to wildlife, reclamation planning should yield methods to provide the necessary physical and vegetational habitat requirements of "target" wildlife species. Specific recontouring or materials handling methods may be required to provide a postdisturbance topography that is both stable and suited to physical habitat needs of wildlife. Revegetation practices must be developed concurrently with recontouring methods to yield a plant community or group of plant communities which meet vegetational habitat needs. Key vegetational features of habitat requiring proper reestablishment include:

- Food value (e.g., forage/browse productivity, availability and quality).
- Cover value (e.g., for protection, specific wildlife activities).

These key features depend upon plant species and growth form composition and pattern within plant communities, differences of such among different plant communities, and spatial arrangement, extent and distribution of different plant communities. Thus, the nature of vegetational diversity, which encompasses the above factors, assumes great importance in habitat reestablishment.

Vegetational diversity may be expressed at various levels, including diversity within defined plant community types and, in a broader sense, diversity among different plant community types. Both levels of diversity may have implications for proper reclamation of oil/gas development disturbances.

Overall diversity within plant communities is influenced by both numbers (i.e., "richness") of plant species or growth forms present and by the degree of evenness of composition and/or distribution among species or growth forms present (i.e., "structural" diversity). In a synecological (the study of ecological relationships at the community level) sense, adequate vegetational diversity within a community may have a number of benefits, the most important of which may be increased functional stability under nonintensive management (Daubenmire 1968). From the standpoint of wildlife, adequate intracommunity (within a community) diversity on reclaimed disturbed lands may promote availability of varied food and cover and hence may provide support for a

wider array of wildlife species (Harju 1980).

As noted by Laycock (1980), the desirability of a proper diversity of different plant community or habitat types has often been ignored in western reclamation to date. The nature of interplant community (between community) diversity is influenced both by the number and characteristics of existant communities over an area, and by the relative size, configuration and arrangement of different existant communities. The importance of these intercommunity and habitat relationships to wildlife has long been recognized (Leopold 1933). Adequate plant community or habitat type diversity, in terms of presence and proper distribution of different communities, is essential for the provision of needed habitat features for wildlife species utilizing more than one habitat type temporally or spatially. Homogeneity of vegetation (low diversity among community types) on and/or around disturbed areas has in fact been indicated to be potentially undesirable for a number of wildlife species (e.g., Boyce and Rothenmaier 1979). Thomas et al. (1979) proposed an index of induced vegetation diversity as especially valuable in wildlife habitat characterization. This index, which is derived from linear measurements of edges between community types, is essentially one means of describing interplant community diversity, and may have some utility (Laycock 1980) in designing and evaluating disturbed land revegetation programs.

To summarize, reclamation planning from a wildlife standpoint should strive to design physical and vegetational habitat conditions on drill site disturbances that have high inherent value and properly complement surrounding undisturbed habitat features in terms of support of important wildlife species. Topographic configuration is the major aspect of physical habitat recreation, while plant community diversity considerations are of prime importance in recreation of vegetational aspects of habitat (i.e., food and cover). Disturbed site revegetation programs should strive to establish sufficient diversity within plant communities to provide both presence and proper structural composition of needed plant species and growth forms. Because interplant community diversity is also of major importance to many wildlife species, disturbed sites may in certain cases be beneficially revegetated to more than a single community type or, perhaps, to a different community type than the surrounding undisturbed area. Consideration of the interplant community, or "habitat" type of diversity in reclamation planning should be based upon area-wide and "key" wildlife species habitat requirement information gained during baseline studies.

Planning for on-site reclamation of sites disturbed by oil and gas development in the Bear River Divide/Overthrust Belt region should, whenever possible, strive to enhance area-wide wildlife habitat values. For example, in some cases it may prove possible to locate access roads or pipeline corridors in a configuration conducive to wildlife migrational patterns. Reclamation could then be structured to provide optimum habitat for such

wildlife movements. In certain cases, habitat diversity and edge effects might be profitably increased by initially revegetating drill pads, access roads, and pipeline corridors to different types of plant communities than surrounding lands--assuming, of course, that the "different" community types will be structured to have habitat value for certain species of wildlife. The benefits of this approach in some situations is suggested by evidence of heavy elk use of drill pads revegetated to grasses and forbs within coniferous forest areas of the nearby Bridger-Teton National Forest (Waldvogel 1984).

IMPLEMENTATION PHASE--POTENTIAL RECLAMATION PRACTICES

The specific reclamation methods and principles discussed below have been developed under environmental conditions similar to the study area and therefore are felt to have high potential for use. Several of the methods are already in use on oil and gas disturbances in the Bear River Divide/Overthrust Belt region. The specific combination of reclamation techniques for any given site should be developed during the predisturbance planning phase in light of site specific conditions and land use goals. Several excellent user guides have been published by the USDA Forest Service as part of the Surface Environment and Mining Program to assist in the implementation of reclamation practices. User guides include: vegetation (USDA Forest Service 1979a), soils (USDA Forest Service 1979b), engineering (USDA Forest Service 1979c), sociology and economics (USDA Forest Service 1979d), hydrology (USDA Forest Service 1979e), and wildlife (USDA Forest Service 1982). The following paragraphs will address site preparation considerations, revegetation technologies, special problems, and other considerations.

SITE PREPARATION

Proper site preparation is essential on any disturbed site to provide a physical base that is stable and will not degrade surrounding lands. The physical base must also be amenable for ultimate establishment of post-reclamation land uses in terms of both physical (e.g., topographic, edaphic, etc.) needs and requirements for proper subsequent revegetation to achieve such uses. Site preparation activities comprise various earth-materials handling and treatment practices including:

- Topsoil salvage and reapplication.
- Regrading and contouring.
- Soil and subsoil amendments.
- Surface and subsurface modifications.
- Site stabilization and moisture conservation.

A brief discussion of each practice follows.

Topsoil Salvage and Reapplication

Salvage of existing topsoil for eventual reapplication has become recognized as a beneficial practice in arid and semiarid disturbed land reclamation. The considerable progress made in topsoiling technology has been reported by Barth and Martin (1982), Schuman and Power (1981), McGinnies and Nicholas (1980), Redente and Grossnickle (1982) and others. Potential topsoiling strategies for enhancement of vegetation diversity on mined lands has been discussed by DePuit (1984). Topsoiling offers a number of potential benefits to reclamation including increased infiltration (Schuman and Power 1980), provision of an improved growth medium for revegetation, increased vegetation diversity (DePuit 1984), reduction of potential erosion (Gilley 1980), provision of propagules and seed of native species (King 1980; Beauchamp, Lang and May 1975), enhanced nutrient cycling (Schuman and Power 1980), and improvement in the availability of essential symbiotic soil microorganisms (Allen 1984; Call 1981). For these reasons and others, Wyoming Department of Environmental Quality Guideline No. 1 (1981) outlines procedures for soil surveys, mapping soils, and estimation of soil quantity (volumes) so that all suitable topsoils can be salvaged and soil characteristics can be evaluated for achieving specified land uses following mining.

The amount of topsoil salvaged and ultimately reapplied following site regrading will depend upon the amount of topsoil initially available, the physical and chemical nature of the underlying subsoil and rooting and growth requirements of plant species to be established. Topsoil is usually applied as soon as possible to minimize erosion losses and reductions in fertility, microbiological activity and indigenous species seed viability associated with prolong storage. Prolonged storage (i.e., greater than 1 year) usually requires that the stockpile be contoured to gentle slopes and revegetated to promote temporary stabilization.

Allen (1984) points out that short-term topsoil storage (fewer than three years) reduced the inoculum potential by soil mycorrhizal fungi by only 10% in North Dakota, but that seven years storage caused a 99% reduction in southwestern Wyoming. She also suggests that although topsoil is often thin and rocky and of apparent poor agronomic qualities, the microbiological qualities should not be overlooked as a source of inoculum. Symbiotic relationships between reclamation species and soil microbes are extremely important for plant establishment, succession, and diversity on disturbed sites, particularly for shrubs since they are more mycorrhiza dependent than grasses.

Barth (1984) conducted an extensive seven year study of soil-depth requirements to reestablish perennial grasses on surface-mined areas in the Northern Great Plains. A total of 15 wedge-type plots were established at active coal mines in Wyoming, Montana and North Dakota. He investigated production of perennial grasses as a function of increasing soil depth over

various spoil materials. He concluded that generic-type spoils lacking distinguishing traits (e.g., acidic or sodic) required a soil layer about 20 inches (in.) deep for maximum grass production. However, in some cases only a thin veneer of soil (2.4 in.deep) was required to maximize production. Application of more than 20 in. of soil was not necessarily beneficial to reclamation objectives. When individual species were examined for soil-depth requirements, wheatgrasses required approximately 16 to 20 in. of soil for maximum production, while green needlegrass required approximately 28 in. of soil . These data also indicated that there was no significant difference in soil-depth requirements between native and introduced grasses. A highly productive, self-sustaining community of cool-season grasses was established on sodic spoil overlain with approximately 28 in. of soil, however, acid spoil was reported as more difficult to revegetate and a soil depth of approximately 39.4 in. was required to achieve grass production comparable with rangelands in good condition. Neutralization or burial of acid spoil may be appropriate reclamation strategies for such material. The measurement of microbial activity as a function of soil depth indicated that approximately 5.5 in. of soil depth over spoil was required to optimize activity of this ecosystem component. Barth (1984)also reported that although the forage quality of plants grown in both spoil and soil was similar, spoil appeared to have a lower ability than soil to supply plants with nitrogen, potassium, and especially phosphorus. Plants produced in spoil generally contained a higher micronutrient content than those produced in soil. No attempt was made to examine soil-depth requirements for shrubs, forbs or warm-season grasses.

Research by Barth (1984) is contrasted with results reported by Redente and Grossnickle (1982) who studied topsoil application over retorted oil shales in northwestern Colorado. Their results indicated that vegetative cover and production of seeded native and introduced grasses, forbs, and shrubs increases with increasing depth of soil cover. However, they reported that native species developed more extensive root systems than introduced species and noted that subsurface barriers to root penetration, such as retorted oil shale or rocks in general, are penetrated by roots of native species but not by introduced species (as reported in the Phase I report, Overthrust Industrial Association 1984).

Most company personnel from the petroleum industry acknowlege the importance of topsoil in establishing successful revegetation programs and recommend topsoil salvage and separation from less productive subsoils or horizons (Overthrust Industrial Association 1984).

Regrading and Contouring

Prior to reapplication of topsoil on disturbed sites, subsoil or development related materials (e.g., drilling muds, petroleum spills,

industrial wastes, etc.) that contain compounds inhibitory to plant growth should be effectively isolated from the surface via adequate burial or covering with subsoil or topsoil, to preclude any undesirable effects to vegetation or animals. Subsoil materials are then generally regraded to produce a topography that: 1) promotes landform stability through reduction of erosion potential, usually through reductions in slope steepness and length; 2) is integrated into local topographic and watershed configurations; and 3) provides a proper surface for proposed future land uses. The latter consideration is especially important from the standpoint of wildlife habitat.

Proper regrading of disturbed sites has been recognized as essential for success in subsequent phases of the reclamation process (Munshower 1982). Verma and Thames (1978) discuss regrading technology which can improve slope stability and produce locally integrated surface hydrology. Landform design can lead to vegetative diversity on reclaimed areas. Wollenhaupt and Richardson (1982) recommend concave surfaces for shrub establishment as the establishment of hardwood shrubs is largely dependent on soil moisture and concave or convergent landscapes tend to concentrate water more than convex surfaces. This can be an important consideration if reclaimed areas are proposed for use as wildlife habitat. However, Munshower (1982) noted that little emphasis has been placed on regrading practices to yield topographic features essential for wildlife use.

Surface slope and exposure (aspect) are important factors affecting revegetation success and the amount of surface runoff (Branson et al. 1962). Creation of terraces or sloping surface contours may provide a means for restoring some of the original topographic relief. Guidelines for constructing terraces, contour furrows, waterbars, etc. are currently published for oil and gas exploration and development (U.S. Department of the Interior 1978). Wright et al. (1974) reported that differences in aspect were responsible for greater seedling establishment on north-facing slopes at the Navajo Mine in northwestern New Mexico.

It is generally reported that maximum vegetative stability cannot be attained on slopes steeper than 33% (3 horizontal: 1 vertical) (National Academy of Sciences 1974: U.S. Department of the Interior 1978). Optimum vegetative stability requires slopes of less than 25% (4:1) (Environmental Protection Agency 1972), and use of agriculture machinery may require that slopes be no greater than 20% (5:1). Caterpiller-type tractors may work slopes effectively of up to 2.5:1 moving up and down slopes, but are safest on slopes of 3:1 or flatter. Narrow slopes (20-40') steeper than 2:1 may use a steep slope scarifier/seeder, but this equipment is currently available only to the Forest Service personnel except on an experimental basis (Monsen 1978; Adolphson et al. 1982).

Amendments

After regrading, topsoil is then usually applied over the recontoured subsoil. Occasionally topsoil availability is low or nil, or the topsoil or subsoil quality is poor due to excessive concentrations of soluble salts or high concentrations of harmful elements. If such problems occur, as indicated by baseline data describing vegetation or soil parameters, then soil amendments or treatments may be required. Richardson (1979b) and Sandoval and Gould (1978) provide reviews of such treatments, many of which have direct or indirect applicability to "problem" soil conditions in the Bear River Divide/Overthrust Belt study area.

The color of subsoil materials is a physical characteristic that may also be detrimental to establishment of vegetation. The high heat absorbability of dark subsoil materials such as shales, or petroleum contaminated soils, may raise the temperature enough to actually kill germinating seeds or young seedlings (Wein and West 1972; Rai et al. 1975). The rate of snow melt on mine spoil in northern Arizona (Thames et al. 1974, Thames and Verma 1975) was considerably quicker than on native rangeland. Surface amendments to moderate the dark color may be necessary to reduce rapid snow melt and runoff. Conversely, a dark surface can be of benefit to seedlings where extra warmth is necessary for early growth.

Surface and Subsurface Modification

Excessive subsoil compaction following regrading may be a problem particularly associated with drill pads and access road reclamation, which if left untreated may hinder plant establishment and physical stability of the site. Topsoil or subsoil spread over a smooth, hard, spoil surface may be subject to slippage or slumping if the hydraulic conductivity of the spoil is sufficiently reduced and if the site is sufficiently sloped.

Alleviation of subsoil compaction via deep ripping or chisel plowing (Hodder 1977; Verma and Thames 1978) prior to topsoil reapplication may therefore often be highly beneficial. Richardson (U.S.D.A. Forest Service 1979) reports that ripping increased both shoot and root biomass production two-fold over biomass production on areas that were not ripped; comparisons were for vegetation in ripping marks and between ripping marks on broadcast seeded areas. Surface compaction may also develop after the topsoil has been applied, thereby requiring scarification with techniques such as shallow chisel plowing to reduce compaction. Scarification usually achieves beneficial results by (Richardson and Packer, 1979):

- Providing soil aeration.
- Providing runoff control and a loose surface for

good moisture infiltration.

- Reducing compaction, which restricts water movement.
- Providing a looser, cooler, more moist soil for seed germination.
- Providing good seed-to-soil contact.
- Providing a temporary modification of soil conditions, such as density aeration, and moisture retention capacity.

Site Stabilization and Moisture Conservation

Two critically important concerns to be addressed during site preparation are site stabilization and water conservation. Without a stabilized surface, subsequent phases of the reclamation process will usually be subjected to delays or, in many cases, total failure (Hodder 1977). Almost without exception, scientists agree that water availability is the factor that limits reclamation in the arid and semiarid west (May 1975, Hodder 1978, Monsen and Plummer 1978). Landform stability and soil stability are integral parts of water conservation procedures.

Macroscale Surface Modifications--Macroscale surface modifications are usually implemented during regrading to produce such gross surface modifications as terraces, swale contouring, and contour trenches. Wright (1976), Hodder (1977), and Verma and Thames (1978) provide reviews of such methods.

Contour trenching has been shown to be an effective means of controlling erosion on several drill sites near Sheep Mountain, Colorado (the ARCO Oil and Gas Carbon Dioxide Projects), providing: trenches are properly constructed so that each trench drains at about a 2% grade; the trenching system is integrated into the overall drainage plan of the area, thus providing for water interception, collection, and energy dissipation; and the trenching system is properly maintained until vegetation is fully established (Unpublished data NPI in Salt Lake City, Utah and the Canon City, Colorado District Office of the Bureau of Land Management). Construction specifications have been provided by Salt Lake County (1981) and the U.S. Department of Interior (1978).

Use of contour trenching in the U.S.A. has been reviewed comprehensively by Upadhyay (1977), with all major research and projects summarized to that

date. It is recommended that the reader obtain a copy of that report for a more thorough treatment of the subject. In general, Upadhyay (1977) concluded that contour trenching provides the most protection from high intensity, short duration rainstorms that cause runoff on areas of depleted vegetative cover. Such climatic conditions are characteristic of the Intermountain area. He also cautioned that trenches may have a detrimental effect, if interception rates from overland flow are too large such that overtopping of the trenches occurs and causes a chain reaction to successive trenches down slope. He emphasized the need for care in designing contour trenches. Two other studies in the Intermountain area have also concluded that contour trenches and gully plugs are effective in catching and holding sediment (Simonson 1970; and Thomas 1975). They suggest that the greater the density of trenches and gully plugs, the longer the life expectancy of the treatments. It was also apparent that the amount of sediment moving in an area has a substantial effect on the life expectancy of the treatments.

Microscale Surface Modifications--Microscale surface modifications such as pitting, contour furrowing, contour chisel plowing, and micro-imprinting are usually made after regrading and topsoiling. The net effect of these methods is to produce a roughened surface enhancing water retention, seed germination, and vegetative growth. Several researchers have created depressions for impeding runoff and creating sites for plant establishment at the Rosebud Mine near Colstrip, Montana (Jensen et al. 1978; Jensen and Hodder 1975). Best seedling establishment occurred within the depressions. Furrows (Nichols 1964), and fan-shaped basins (Frost and Hamilton 1965) have been used successfully to reestablish vegetation. Ten years following pitting in Wyoming, Rauzi (1968) reported that infiltration rates were higher in all pitted treatments. During periods of below average precipitation in Texas, Thomas and Young (1956) reported that seeding in conjunction with pitting was the only successful way to establish grasses. In Arizona rangelands, pitting, followed by cultipacking was found to be the most reliable method of establishing vegetation (Anderson et al 1957). In southern Arizona, Slayback and Cable (1970) found that large pits, about 6 in. deep, 18-24 in. in length, and .5 to 1 in. wide were responsible for plant growth 2.5 times that of conventional pitting and five times that of untreated range. The larger pits were more effective in reducing runoff and prolonging soil moisture availability. Large basins have also been reported to be effective in reclaiming bare scalped areas for seeded species (Newman 1966).

Research by NPI in stabilizing sandy areas along the Alaskan Highway Gas Pipeline of Saskatchewan, Canada, suggested that the modified Hodder gouger appeared to achieve greater plant establishment and cover than conventional drilling methods where the seed tended to become buried too deeply or the seed was uncovered completely by drifting sands (Unpublished data by NPI and David Walker Assoc., Ltd.). However, research by NPI in northeastern Utah and

northwestern Colorado suggested that poor results are achieved if soils have a high clay content (Unpublished data by NPI). Such depressions collected too much water and soil fines, burying seeds too deeply or covering and killing slower growing shrubs once they had germinated.

Water Harvesting--In many arid and semiarid areas opportunities for water harvesting can be created by contouring and reshaping the surface. Water available for plant growth can be doubled by concentrating it in small basins. Various reports in a water harvesting symposium (Fraiser 1974) outlined ways to apply surface treatments for obtaining controlled runoff. Some of the principles of water harvesting may find useful application in revegetating disturbed sites in arid regions. McKell (1975) proposed a system employing surface runoff from treated slopes and native plant species for rehabilitating oil shale disposal areas in eastern Utah. His concepts have been subsequently tested under field conditions and appear to be successful. Malek (1980) was able to significantly increase the amount of water harvested from slopes by treating them with surface stabilizing materials. Aldon and Springfield (1975) created small catchment basins and thus increased shrub transplant survival in New Mexico. A rock mulch may also have the effect of concentrating the rainfall received to the spaces between rocks while at the same time reducing the amount of surface evaporation.

REVEGETATION

Several activities may be required for the successful revegetation of petroleum-related disturbances. These activities may be grouped into the following categories for discussion purposes:

- Species selection
- Seeding methods
- Planting methods
- Mulching
- Cultural treatments and ammendments

A discussion of each category follows.

Species Selection

The selection of adapted species for disturbed lands is a challenging process. Only a few publications provide information on the subject. Cook et al. (1974), Plummer et al (1968), Campbell and Herbel (1975), Power et al. (1975), Plummer (1977), USDI Fish and Wildlife Service (1977 and 1978), Van Epps and McKell (1978 and 1979), Institute for land Rehabilitation (1979), USDA Forest Service (1979), Vallentine (1980), Briede (1981), and the USDA Forest Service (1983) mention problems associated with species selection and provide information on the suitability of species for reclamation.

Successful selection of proper plant materials for reclamation depends on numerous factors. Power et al. (1975), Kesten (1977), Van Epps and Mckell (1978), and the USDA Forest Service (1983) advise that prior to the species selection process, the environmental conditions of a site should be evaluated. This is usually done as a baseline study of predevelopment conditions as described under the predisturbance planning phase. In selecting species, Hanks et al. (1971), Plass (1973), Bauer et al. (1975, 1976), Van Epps and McKell (1978), McArthur et al. (1979) and the USDA Forest Service (1983) point to a high variability among plants within the same species, subspecies or even biotype. Therefore, Jaynes and Harper (1978), and Van Epps and McKell (1978) stress using species that have demonstrated an ability for establishment on disturbed sites in the vicinity of the disturbed area. Seeds produced by these plants should have a greater chance of success than plant materials selected from other sources and locations.

A considerable amount of literature has accumulated on general characteristics of both native and introduced plant species for disturbed site revegetation in the West. More familiar publications include: Sutton and Johnson (undated), Vories and Sims (1977), Eddleman (1977), Monsen and Plummer (1978), Long (1981), Thornburg (1982), and Wasser (1982). The USDA Forest Service (1983) has published the proceedings of two symposia on improvement of range and wildlife habitats in the Intermountain region. Species recommendations are made for revegetating wildlife habitats in major plant communities in the Intermountain ranges and new advances in plant selection and development are reported by numerous researchers. Pertinent papers include:

- Species adapted for seeding mountain brush, big, black, and low sagebrush, and pinyon-juniper communities
- Plants for revegetation of riparian sites within the intermountain region
- Characteristics and uses of important grasses for arid western rangelands
- Grasses for revegetation of mountain sites
- Plants adapted to summer rangelands
- Promising new grasses for range seedings
- Legumes -- their use in wildland plantings
- Nonleguminous forbs for rangeland sites
- Some promising chenopods for use on disturbed lands
- Use of rosaceous shrubs in wildland plantings in the intermountain west
- Important shrubs for wildland plants, Compositae
- Improving the nutritive value of winter range forage

The proceedings also report various aspects of habitat management such as vegetation requirements for fisheries habitats and managing vegetation for pronghorns in the Great Basin.

Criteria for evaluating plant species for reclamation have been divided and discussed under several major headings, including:

- Success in Propagation and Establishment. Specific criteria are considerations such as availability of seeds and vegetative material, capability for propagation by the use of seed and vegetative material, ease in planting, and success in establishment (Institute for Land Rehabilitation 1979; West et al. 1972; Young et al. 1981; Bleak et al. 1965; Plummer et al 1968; Graves et al. 1978; McKell 1978; Van Epps and Mckell 1978, 1980; Frischknecht and Ferguson 1979, McKell and Van Epps 1980; Vallentine 1980; Eddleman 1978, 1980; Whalley et al 1966; and Plummer 1943).

- Adaptation to Animal Uses. Important criteria include: palatability, nutritive value, tolerance to herbivory, consistent productivity, ease for animals to obtain forage, above-ground growth rate/forage production, below-ground growth rate, cover, season of maximum growth (Vallentine 1980; Hurd and Pond 1958; Plummer et al. 1968; Stoddart et al. 1975).

- Tolerance to Weather Extremes. Extremes may be classified as drought, extreme temperature, and high velocity wind (Eavis 1972; Eddleman 1978, 1980; Van Epps 1975; Bannister 1979; Levitt 1958; Larcher 1973; Rorison 1967; Oke 1978; Whitehead 1963; Tranquillini 1970; USDA Forest Service 1979).

- Adaptation to Harsh Soil Conditions. Criteria include: soil moisture stress, salinity, unfavorable pH, nutrient deficiencies/toxicities, soil texture,and wet conditions/water logging (Ludeke 1977; Wali undated; Institute for Land Rehabilitation 1979; Vallentine 1980; Richardson and McKell 1980a, 1980b; Power et al 1974; Safaya 1979; McGinnies and Nicholas 1980; and Branson et al 1981).

- Erosion Control. Subcriteria already defined in previous criteria are: rapid below-ground growth rate, and above-ground growth rate and cover (Dunne and Leopold 1978; and Branson et al 1981).

- Desirable Plant Characteristics. Vegetation parameters to be considered include: persistence,

self-renewal, compatibility with other species, disease and pest resistance, fire resistance, landscaping value/aesthetic quality, and minimum maintenance costs (Plummer et al 1968; Vallentine 1980; Institute for Land Rehabilitation 1979; Harthill and McKell 1979; USDA Forest Service 1979; and Plummer 1977).

In short, mixtures of plants designed for permanent revegetation should contain species which are well-adapted, reasonably readily establishable, competitively compatible, useful for proposed land uses and reasonably available for seeding or transplanting.

As noted by DePuit (1982), most success in disturbed site revegetation in the West to date has been achieved for perennial grasses, while successful revegetation with shrubs and forbs has been less common. The importance of these plant forms to wildlife in revegetation programs, however, has been commonly recognized (e.g., Frischknecht 1978). Although existing sources of information on shrub and forb selection and establishment procedures (e.g., Plummer et al. 1968; Vories 1980; Monsen and Christensen 1975; Stelter et al 1981, and others) may yield valuable information and should be consulted, more research is clearly needed on shrub and forb establishment on disturbed lands.

Proper design of the species mixture can profoundly affect inter- and intra-plant community diversity on mined lands. As noted by Coenenberg (1982), development of different community types on disturbed lands may be more rapid if specifically designed, different species mixtures are utilized on sites with varied environmental conditions, rather than universal use of "standard" species mixtures. DePuit (1982) discussed several strategies in seed mixture design which may increase intra-plant community diversity on mined lands, including manipulations of species numbers and relative composition in species, growth form and life form, in mixtures based on community (competitive) relationships among species. While principles such as these may have applicability for the Bear River Divide/Overthrust Belt study area, specific information on proper species-mixture design for disturbed sites in the study area is lacking. Future reseach will help clarify many uncertainties that present themselves in achieving targeted reclamation landuse objectives.

Seeding Methods

In addition to proper species selection and mixture design, successful revegetation of oil and gas disturbances in the study area also depends upon implementation of sound methods of establishment. Vegetation may be established on disturbed sites by either or both of two broad approaches:

seeding and transplantation. A discussion of seeding follows; transplantation will be discussed under "Planting Methods".

Considerable progress has been made in direct seeding technology for disturbed sites in the arid and semiarid West in the past decade (e.g., DePuit 1982; Cook et al. 1974, Packer and Aldon 1978, and Vallentine 1980). Major success in seeding has generally been limited to perennial grasses and secondarily, forbs. As noted by DePuit (1982), success in direct seeding depends upon proper:

- Seedbed preparation.
- Selection and implementation of seeding methods.
- Timing of seeding.
- Seeding rates.

Seedbed Preparation--The ideal seedbed has been defined by Vallentine (1980) as being: 1) very firm below seeding depth; 2) well pulverized and friable on top; 3) not cloddy nor puddled; 4) free from live resident plant competition; 5) free from seed of competitive species; and 6) containing moderate amounts of mulch or dead plant material on the soil surface. Many spoil materials or even stockpiled topsoil lack some of these desirable characteristics and may require modifications through preparation of the plant growth medium. Seedbed preparation consists of various primary and secondary tillage (cultivation) practices designed to: 1) provide soil aeration; 2) provide erosion control and increase water infiltration; 3) reduce excessive soil compaction; 4) provide a looser, cooler, more moist soil for seed germination; and 5) improve seed-to-soil contact. Selection of the types of tillage needed depends upon consideration of both site conditions (edaphic and topographic) and seeding methods to be employed. Broadcast seeding, for example, may often require only primary tillage practices (e.g., chisel plowing) to produce a moderately rough seedbed, whereas most drill seeding methods require a smoother, firmer seedbed achievable only with secondary tillage practices (e.g., disc plowing, harrowing and/or cultipacking). Richardson (1979) provides a good review of seedbed preparation methods on disturbed sites in the West; many of these methods certainly have direct or indirect applicability on oil or gas disturbances in the study area.

Selection and Implementation of Seeding Methods--Regardless of the technique selected, all seeding methods share common goals of placing seeds in contact with the soil, properly covering the seeds, where possible, and firming up soil around the seeds. Selection of the "best" seeding method for disturbed land revegetation depends upon an integrated consideration of seed

relatively low amounts (200 to 500 lbs./acre) are used as a "tracer" to tell where the seed mixture has been applied, and to reduce the risk of seed damage. Regardless of the type of hydromulcher used, Kay (1977) reported an initial reduction in germination of 10 to 15%. Two of the major problems with hydroseeding is the minimal coverage of seeds with soil and the dependence on local water supplies.

For the reasons noted above the addition of fertilizer to the seed mixture is not recommended. Seed should be applied in one pass and any fertilizer or fiber mulch in a second pass. Slow-release fertilizers are often broken down by the hydromulch application. On very steep slopes, a tackifier is often added to the seed solution to hold the seed to the slope and reduce subsequent erosion or washing of the seed. There is usually a reduction in germination from the tackifier such that its use should be restricted to areas characterized by smooth, steep slopes where there is a high probability of loss of seed by colluvial or alluvial erosion processes.

Timing of Seeding--Recommendations for fall seeding are generally made for the areas of Colorado, Utah and Wyoming (National Academy of Sciences 1974) and for the mountainous areas of the West where about 70% of the precipitation is received as snow (Cook et al. 1974). Other guidelines for Wyoming recommend seeding in either late fall or early spring for cool season grasses (Beauchamp et al. 1975). Vallentine (1980) suggests that early spring seeding is effective providing that the seedbed was prepared the previous fall and that seeding is done within a few days after it is possible to get on the ground. In a Utah foothill study, about 80% more fall planted seedlings were alive at the end of the second growing season than spring planted seedlings, but there were no differences in production three years after seeding (Cook et al. 1967). For Utah roadsides, in most cases, late fall seedings, from about September 15 to November 15 were best (Cook et al 1970). Early fall seedings, August 15 to September 15 or spring seedings, March 15 to April 15 were less successful. Late spring seedings, from April 15 to May 15 failed in almost all trials. Early spring seedings, if completed during the last two weeks of March or the first week in April were moderately successful but were not as satisfactory as fall seeding. This was generally true, regardless of species or seeding method (Cook et al. 1970). Spring seeding gave a greater number of seedlings but the mortality during the summer was extremely high. Lack of adequate precipitation and higher evaporation rates were the major reasons for this greater mortality.

Hodder (1976) recommended spring planting in areas subject to wind erosion during the winter. Recommendations for steep road cuts in Montana suggested that success ratings were consistently higher for spring seedings in the steep cut slope and fill slope categories (Hodder 1970). Spring and fall seedings at ARCO Oil and Gas Company's Sheep Mountain Carbon Dioxide Project near Pueblo, Colorado suggest that spring seedings are more effective on steep

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slopes (e.g., 1:1) than fall seedings because seed applied in the fall tended to slough or wash off during the winter months resulting in less seed to germinate in the spring (NPI unpublished data). However, on flat areas that were less subject to sloughing and erosion, fall seeding was superior to spring seeding.

As noted by Cook et al. (1974), timing of seeding should be scheduled to coincide with seasonal periods of climatic conditions (precipitation and temperature) most conducive to vegetation growth and, to as great an extent as possible, to match seasonal germination needs of plant species seeded. Packer (1979) noted fall and winter to be optimal seasons for seeding to meet these requirements in the Intermountain Region (which includes the study area), and discussed advantages and disadvantages of each. DePuit (1982) further recommended late ("dormant") fall or early spring as optimum seeding seasons, since early ("active") fall and late spring season carried more significant risks due to climatic patterns and/or variability. Therefore, it would appear that late fall (mid October through late November) and early spring (late March through early May) may comprise the "best" seasons for seeding disturbed sites in the Bear River Divide/Overthrust Belt study area.

Seeding Rates--Direct seeding rates for individual species and species mixtures should always be derived on a pure live seed (PLS) basis. Seed testing to evaluate purity and germination should have been performed recently to ensure an accurate determination of PLS values. It has been noted that seed tested within the last six months have shown appreciable decreases in PLS values for some species (up to 100% reduction), while others have retained their viability for several years. Maintenance of PLS values often depend on conditions beyond control of the seed company and may be peculiar to a specific seed lot. The minor cost of a seed test for each species is well worth the investment if large quantities of seed are to be purchased. More reputable seed companies will have their seed lots tested at least on a six-month basis. Great risks are assumed by the consumer if seed is purchased without such testing.

Seed mixtures should be based upon an integrated consideration of: 1) seeding method employed; 2) site characteristics; 3) desired plant density and community composition; and 4) characteristics of species seeded (DePuit 1982). Some authors suggest that the seeding rate should be lower on arid sites than on humid sites and higher on steep slopes where seed tend to slough or be eroded from the surface than on flat surfaces. Plummer et al.(1968) generally recommend 11 lbs. of seed per acre for drill seeding of well-drained soils in semi-arid lands. Vallentine (1980) recommends 30 seeds per square foot for small seeds, 20 seeds per square foot for medium size seeds, and ten seeds per square foot for large seeds. These seeding rates were recommended for reestablishment of rangeland pastures and relatively flat terrain. Cook et al. (1974; 1970) recommend seeding rates for drill seeding in foothill

areas be about 15 lbs. of PLS per acre on south and west exposures but only about 7 to 10 lbs. on east and north exposures. On more critical sites, they recommend that the quantity of seed be increased by 50 to 100%. Seeding recommendations should be modified according to seed size and weights. Seed that is drilled tends to establish in rows leaving spaces of 7 to 14 inches of bare ground between rows. With time, there is a gradual filling in of the bare area but it is seldom completely filled in arid or semiarid areas even when rhizomatous species are used. For this reason it is important that drilling be oriented with the contour to discourage the erosion downslope that may develop between rows if the drilling were oriented against the contour. Exception to this might be if the area were ripped with the contour and then seeded against the contour with a Brillion seeder, which spaces rows one to two inches apart. This method is preferred when slopes are rather steep and seeding with the contour would encourage slippage of the seed drill.

For broadcast seeding, the amount of seed should be doubled (Cook et al 1979, 1974; Packer and Aldon 1978; Vallentine 1980; Vallentine et al. 1963). Seeding rates on harsh disturbed sites should always be calculated to apply greater numbers of pure live seeds per unit area than the minimum required to yield desired plant densities, because not all seeds will germinate or seedlings survive. However, seeding rates should only be increased up to the point necessary to assure adequate densities of established plants, since overly high seeding rates have sometimes been noted to induce reduction in overall plant community vigor and diversity (e.g., DePuit et al 1980). Relative seeding rates among individual species in a mixture should be manipulated in light of desired plant community composition in conjunction with seed, seedling and mature plant characteristics of individual seeded species (e.g., seed size and weight relationships, relative ease of germination and establishment, relative vigor and competitiveness, etc.). Site-specific research within the study area will be required before firm recommendations on required seeding rates for mixtures and species within mixtures can be made which properly conform to the above principles.

Planting Methods

Transplanting live plants or plant parts comprises the second broad approach to revegetation of oil or gas disturbances in the Bear River/Overthrust Belt study area. Transplanting is generally more expensive than direct seeding, and has generally not proven necessary for perennial grass establishment on semiarid disturbed sites. However, many areas of land disturbance are in regions of less than about 9 inches average annual precipitation which is too low to consistently ensure seed germination and plant establishment from direct seeding (Van Epps and McKell 1980). Bleak et

al (1965) concluded that direct seeding would not be successful in salt desert shrub environments. Transplanting of container-grown seedlings, rooted cuttings, root sprouts and wildings that have grown beyond the early seedling stage is a viable alternative for revegetation sites below about 8 inches of precipitation. The main advantage of transplanting when compared to direct seeding is success in plant establishment (Hines 1973; Van Epps and McKell 1980). Plummer et al. (1968) reported that early spring transplanting of one to two year old seedlings virtually assured establishment on rough, eroded sites. Aldon (1970, 1972) concluded that fourwing saltbush could be successfully transplanted to harsh sites when soil moisture was adequate.

Plant materials associated with specific transplanting methods include:

- Bare-root transplants
- Container-grown transplants
- Mature-plant transplants
- Root or rhizome sections
- Sod or root pads

Transplanting methods have been developed for each type of plant material, all of which may have utility in the study area depending on site conditions. These methods may be used alone or in combination with direct seeding as a means of establishing species not suited for direct seeding (e.g., some shrubs and trees) and as a means of increasing diversity.

Two important concerns in using container-grown plants are adequate size and sufficient hardening. Hodder (1970) reported that when plants are not of sufficient size or are not hardened (i.e., physiologically adjusted to stress conditions outside), transplanting success was reduced. Moghaddam and McKell (1975) noted a decline in survival of fourwing saltbush transplants when they were taller than about 5 in. Specific recommendations for other species have not been reported. Plants grown in containers should have a well-developed root system to hold the rooting medium together, but excess root mass or shoot mass should be avoided.

The success of establishment and ease in planting of containerized material depends to a large part on the type of container. Barker (1978), Barker and McKell (1979), and McKell and Van Epps (1980) found that the success of the containerized plants in the field was influenced by the size and shape of the container. Among woody species used for erosion control along Arizona highways, Hogan and Cole (1965) reported increased survival as container size increased. Ferguson and Monsen (1974) reported that many

desirable browse species were easily established on depleted deer winter ranges using containerized transplants. On strip mine spoil, Dollhopf and Majerus (1975), May et al. (1971), and Orr (1975) had considerable success in transplanting several woody species.

Transplanting techniques presently utilized in forestry have been shown to be economical and dependable for shrub and tree establishment (Tinus et al. 1974). Successful techniques involving the furrowing of rangeland and planting soon after rain storms are being used in Israel to transplant saltbush (Orev 1970). It is possible that successful revegetation of harsh sites in low precipitation areas in the future will depend heavily upon similar concepts (Aldon 1972). Although present costs are high, transplanting may be more economical than direct seeding in some cases because of its higher success rate.

Sindelar et al. (1973) reported that both shrubs and trees could be successfully transplanted in a soil mass using a front-end loader to remove an approximate one foot layer of roots, crowns, stems, and soil and then planting the excavated root soil mass into a depression. Similar use could undoubtedly be made of scrapers to remove grass sod to transplant it into other areas (Dietz 1975), as long as sufficient consideration was given to the impact on the borrow site.

Transplanted grasses have demonstrated excellent survival on severe sites. May et al (1971) worked with sprigging and sodding methods using saltgrass and western wheatgrass. Sodding was definitely superior to seeding in terms of plant growth and survival. Aldon (1973) and Aldon and Springfield (1975) reported that transplants of western wheatgrass and alkali sacaton could be easily established if grown in containers and then field planted when soil moisture was high.

Techniques and scheduling for planting and establishing shrubs on wildland disturbances are reported by Stevens (1981), Penrose and Hansen (1981), Shaw (1981), Ferguson and Frischknecht (1981), and the USDA Forest Service (1979). Other research on transplantation methods have been conducted (e.g., Van Epps and McKell 1980; Packer 1979; Crofts and Parkin 1979; and others) which may have applicability in the study area.

Mulching

Temperature, moisture, and other environmental factors often limit plant establishment. Consequently, mulching or the application of plant residues and artificial substances to the soil surface often ameliorate

microenvironmental extremes. Smith (1981) reviewed the effects of mulches on vegetation establishment in southwestern Wyoming and reported that: It has generally been agreed upon that mulching benefits revegetation efforts by temporarily providing protection for the soil surface against erosion, retarding evaporation, increasing infiltration of rain-water, protecting the soil and seed against the impact of raindrops, intercepting surface runoff, reducing soil temperature ranges, and generally increasing seedling establishment (Bond and Willis 1969; May et al. 1971; Springfield 1971; Kay 1978; and USDA Forest Service 1979). Smith (1981) reports: conversely that, Hopkins (1954) found that mulch can retard the initiation of growth because the soils warmed more slowly than normal; that Weaver and Rowen (1952) concluded that too much mulch caused excessive water stress by intercepting precipitation followed by evaporation; and that Gould et al. (1975) felt that hay and straw mulching may be detrimental to the establishment of native range plants due to the competition from seeds contained within the mulch.

Mulches and Erosion Control Practices--Kay (1983) reports that straw can be expected to contain 0.5 to 5.0% cereal seed by weight. Straw applied at a rate of 3000 lbs./acre, could contain from 15 to 150 lbs. of seed that could produce plants that could compete with native species. For most mulching operations, it should be specified that straw come from certified weed-free fields. County extension agents usually make such certifications. Such straw is more available in areas growing cereal grains for resale as planting seed, where the seed needs to be pure. If certified straw is unavailable then it should be inspected and rejected if it contains more than reasonable amounts of weeds.

Native hay on the other hand, may contain seed that is compatible with the seed mixtures used, thereby increasing viable seed applied to the site. Darling and Young (1984) compared the results of mulching using native hay and wheat straw and concluded that native hay is at least as effective as wheat straw in reducing erosion, and, depending upon its seed content, may be more effective. Needle-and-thread grass was reported to be successfully introduced using native hay mulch, as conventional seeding often does damage to the long seed. However, they cautioned that undesirable species may be introduced with native hay mulch which may limit the growth of seeded species through shading and depletion of soil moisture and nutrients, and that hay free from seeds of aggressive weedy species should be used to optimize the establishment of desirable species. They also suggested that when compared to non-mulched sites both straw and native hay mulch can improve plant community diversity, evenness, and floristic richness by introducing additional species.

Research at two sites in Wyoming (Shirley Basin and Hanna), compared the use of straw, standing stubble, and other organic mulches on newly seeded reclaimed areas to minimize soil erosion and aid in seedling establishment

(Mason et al. 1980). They reported that grass establishment was slightly better in the standing stubble than in the crimped straw treatment, and that the standing stubble was more effective in trapping snow than the crimped straw treatment, which can result in greater moisture. Water infiltration was also enhanced by the standing stubble. The use of feedlot compost did not result in improved seedling establishment and the cost was reported to be several times the cost of the standing stubble method. Compared to crimped straw (or hay) the cost of establishing a standing stubble was only 5 to 25% as high, with much less chance of major weed infestation.

Researchers also differ as to recommended types of effective mulch. Packer et al. (1976, 1978) indicate that straw was the most effective and widely used of the common mulches. Dudeck et al. (1970) found excelsior mat or jute to yeild the best results of 11 mulch treatments tested. In the 15-inch precipitation zone in the Central Great Plains, Vallentine (1980) reports that the risk of failure in range seedings has been high and the establishment of stubble for erosion control has been avoided where possible because of the moisture needed for the cover crop. Smith (1981) found wild hay mulch at two tons per acre far superior to fabric mulch (woven paper strips), barley stubble, or the non-mulched control at Green River, Wyoming.

Jacoby (1968) evaluated jute netting, straw mulch, snowfence, irrigation, and combinations of these moisture conserving treatments on revegetation of coal spoil banks in southwestern Wyoming. Results concluded that moisture was a main limiting factor to plant establishment, but that it could be supplied through snowfencing and irrigation; snowfence was effective only when placed on the leeward side of large, open, level areas. Mulch was necessary for good seedling establishment but required a means of being held in place. The results also suggested that successful revegetation was dependent on stabilization of erosion on slopes. Treatments such as jute netting, use of older spoil bank material, irrigation, and topsoil were all helpful in accelerating vegetative stabilization of spoil banks.

When available, native hay mulch is considered more cost effective than straw mulch (EPA 1975). Cereal straw is somewhat less effective than hay because it is smooth (has no barbs) and therefore, is more difficult to anchor (Chepil et al. 1963). Straws of other grains, such as oats, barley, rye, and rice, are about as effective as wheat straw. Brammer and Theisen (1982) report that the greater the fiber length of the mulch the more effective the mulch is at providing its benefits. For this reason, they feel that long fibered hay mulches are superior to straw mulches which in turn are superior to hydromulches.

Vegetative mulches are generally reported to be more cost effective than other mulching materials. For example, Chepil et al. (1963) compared vegetative mulches to resin-in-water emulsions, asphalt emulsion and cutback

asphalt, latex-in-water emulsion, gelatinized starch solution, ammonium lignin sulfonates and sugar solutions, sodium silicate and calcium chloride solution, gravel, stones, and crushed rock, and found that no mulching material tested excelled well anchored vegetative mulch in both cost and effectiveness in controlling wind and water erosion of denuded land. May et al. (1971) reported netting and barley straw treatments to give better results than other treatments used. Monson (1978) found straw mulch and netting superior to broadcasting or hydroseeding without mulch on steep slopes using a predominantly grass seed mixture. Kay (1983) found straw mulching superior to wood fiber mulch at 1500 and 3000 lbs./acre and over the bare ground control. Jute and straw were also found to be superior to "hold/grow" or excelsior.

The influence of increasing rates of straw mulch on reducing soil loss have been documented by Kay (1983) and by Meyer et al. (1970). From these data it appears that anchored hay or straw mulch at about 3000 lbs./acre is more effective than other more expensive treatments such as excelsior, jute or "hold/grow". Native hay is slightly denser than straw and because of its longer fibers it is often more difficult to spread than straw mulch and more costly to apply as it has to be spread at a slightly higher rate to ensure uniform coverage. The use of tackifier on heavier applications of straw mulch usually results in peeling and loss of the mulch cover under windy conditions.

Mulch Anchoring Techniques--Several techniques are available for holding the hay or straw mulch in place. The most commonly used are disking, chemically tackifying, and netting. Disking is generally used on relatively flat slopes (e.g., 3 horizontal : 1 vertical) accessible to equipment. Steeper slopes (e.g., slopes steeper than 2:1) that are relatively accessible to equipment by adjacent access, can be treated with chemical tackifiers using hydromulching equipment. On extremely steep slopes (e.g., 1.5 : 1 to 1:1) netting is preferred. Brammer and Theisen (1982) compared Mulchnet brand paper netting over straw with jute netting over straw, and straw mulch tackified with 120 lbs. of Terra Tack-AR and 400 lbs. of Conwed hydromulch (in 1500 gal. of water) per acre and found the tacked straw to be the most effective treatment. They recommended plastic netting on slopes steeper than 2:1.

Kay (1977) compared chemical tackifiers and found asphalt and Terra Tack superior to other treatments. Hodder (1970) also found asphalt to give good results in Montana. In remote or environmentally sensitive areas Terra Tack appears to be more desirable. Terra Tack, or comparable organic products, appears to be cheaper, cleaner, easier to use, and just as effective as asphalt for tacking mulch.

High winds may contribute to soil drying and plant moisture stress in Wyoming (May,1975). Most of the land form and soil stability methods

discussed above offer some protection from wind. Artifically constructed windbreaks such as snow fences and soil ridges or shelter belts of vegetation retard erosion and increase water availability as demonstrated on mined land sites within the immediate study area (e.g., May et al. 1971) and adjacent areas (Jacoby 1968). A reference list for snow management on the plains, as compiled by the Snow Management Committee of the Great Plains Agriculture Council is provided in Appendix B. The reference list was made available at the Wildland Applications of Blowing Snow Management Workshop held in Laramie, Wyoming on March 1-2, 1983.

Cultural Treatments and Ammendments

Fertilizer-- Most soils in arid or semiarid regions are low in the plant macronutrients nitrogen (N) and phosphorus (P), which suggests potential benefits of N and P fertilization. Relatively few range soils in the West are apparently deficient in potassium (K). Research on disturbed lands in many parts of the West has demonstrated positive effects of N-P fertilization on revegetation; considerable progress in N-P fertilization methods has been made which might be applicable to the study area (e.g., Bauer et al. 1978; Berg 1980; and others). However, in the Intermountain region, nitrogen has been the main fertilizer element used for increasing plant growth and productivity (Vallentine 1980). Experience has shown that fertilizer application on arid range soils often will not increase yields unless additional moisture is applied and, in fact, the early growth stimulated by fertilizer may increase the rate of soil moisture depletion (McKell et al. 1959). However, fertilization may be essential for establishment of vegetation on spoil material (Power et al. 1975). On arid sites moderate amounts of fertilizer would need irrigation to be effective. Rai et al. (1975) reported that all soil samples taken from coal-bearing formations in northwestern New Mexico were adequate in major plant nutrients with the exception of N. In northern Arizona, Thames et al. (1974) and Thames and Verma (1975) reported that plant nutrients N, P, K and calcium (Ca) were all higher on mine spoil than on undisturbed adjacent land. Van Epps and McKell (1980) compared the survival and growth of container-grown transplants receiving fertilizer with those not fertilized at the time of transplanting and found that survival was not increased by fertilization even though plant growth was increased.

The effectiveness of fertilization is closely related to water availability, and reduced vegetation responces to added fertilizer have often been noted concurrently with increasing aridity. Also, excessive fertilization rates and/or durations on disturbed lands have sometimes induced undesirable effects on species composition and/or diversity (e.g., Patterson and Youngman 1960; DePuit and Coenenberg 1979). Therefore, fertilization may be less beneficial on more arid oil or gas disturbances in the study area, and

when fertilization is employed optimal results may be expected under lighter fertilization regimes. Site-specific research within the study area will be required to prove or disprove the absolute need for fertilizer applications.

Nurse Crops--Spoil materials are usually low in organic matter. Therefore, annual plants, such as small grains, could provide a rapid ground cover and supply an aboveground and below-ground biomass to increase the organic matter content of the spoil materials which correspondingly increases the water and nutrient holding capacity of the soil. However, Evans et al. (1970) pointed out that agressive annual grasses such as cheatgrass brome, are very competitive for soil moisture and may prevent the establishment of seeded species unless some provisions are made to favor them. Nevertheless, weakly competitive annuals or perennials can be useful as a companion nurse crop (McKell and Finnis, 1957) or desirable species can be seeded into dead stubble. In Montana, several annual grains and grasses were successfully grown on regraded spoils where they added from about 500 to over 1000 lbs./acre of above-ground organic matter (Sindelar et al. 1973). In areas of limited rainfall (less than 10 in.) nurse crops are not advised because they may deplete the soil moisture. In weedy areas, some means for controlling weed competition may be necessary.

Irrigation--Due to limited water availability in the study area, supplemental water would have beneficial effects on revegetation. Progress in disturbed site irrigation technology has been made elsewhere in the West (e.g., Ries and Day 1978) which may be directly or indirectly applicable on oil and gas disturbances in the study area. Irrigation should be limited to minimum quantities and durations necessary to assure adequate establishment only, however, due to potentially undesirable effects of over-irrigation on plant morphology and community characteristics (Ries and Day 1978; DePuit et al. 1982). Irrigation may have limited practicality for revegetation in the study area due to unavailability of water in sufficient quantity or quality.

MISCELLANEOUS RECLAMATION PROBLEMS

Because of the great diversity and volume of reclamation topics that could be addressed relative to oil and gas development in the study area, it is necessary to limit the literature review to those that are of primary concern for mitigation of adverse wildlife impacts. However, there are secondary concerns that from time to time may be considered important to reclamation efforts; a brief discussion is provided for these topics. Selected lists of pertinent literature have also been provided in the

appendices for selected topics.

Snow Management

Throughout much of the study area blowing snow may present problems to the revegetation efforts. Guidelines for handling such problems have been developed for mined land reclamation (USDA Forest Service 1980). Much information and expertise has been developed by the Snow Management Committee of the Great Plains Agriculture Council. Appendix D contains a reference list for snow management on the plains as developed by the Snow Management Committee. Further assistance on specific problems is available from research scientists located at the Laramie, Wyoming offices.

Riparian Habitat Rehabilitation

One major area of concern expressed by several wildlife biologists and wildlife organizations regarding development of petroleum resources in the study areas has been for rehabilitation of disturbed stream habitats. Like reclamation, research on rehabilitation of stream habitat is relative new in the study area. Based on literature reviews and person interviews to date, it appears that most research in the study area has been conducted by Bruce Smith, BLM Fisheries Biologist in the Rock Springs, Wyoming District Office. Other work on mitigating adverse impacts to stream habitats have been presented by Hall and Baker (1982) and Swanson (1979). A bibliography has been prepared regarding stream rehabilitation techniques applicable to oil and gas resources development in the study area (Appendix E). The material presents an overview of the literature.

Reclamation Equipment

The most comprehensive review of reclamation equipment is presented by Larson (1980). The publication describes the structure and operation of equipment designed or adapted for range and wildlife habitat improvement and disturbed land rehabilitation. Major manufacturers or sources of information have been listed to assist the reader to become knowledgeable about reclamation equipment. Copies of the publication are available from the Superintendent of Documents, U.S. Government Printing Office Washington, D.C. 20402, Stock No. 001-001-00518-5.

MANAGEMENT AND MONITORING PHASE--POTENTIAL RECLAMATION PRACTICES

Proper management of disturbed sites during and after initial reclamation is critically important (Packer and Aldon 1978). However, as noted by Power (1978), little research on management practices for disturbed lands in the arid and semiarid West has been conducted. For this reason, little information on management in other areas is available for extrapolation to the Bear River Divide/Overthrust Belt study; principles stated in the following paragraphs can hence only be taken as tentative. Post-reclamation management of reclaimed oil and gas disturbance sites thus comprises a major area of needed future research.

Management practices may be employed to perform protective, corrective and manipulative functions on disturbed lands. Packer and Aldon (1978) noted initial protection of newly revegetated areas from excessive herbivory to usually be an essential management practice, due to the attractiveness of new seedlings to herbivores coupled with low initial tolerance to defoliation. Affording such protection to extensively disturbed drill pads, access roads and pipeline corridors following revegetation would be extremely expensive utilizing conventional fencing methods, and may in fact be infeasible. The use of electric fencing is suggested by the Bureau of Land Management in Rock Springs, Wyoming as a more inexpensive alternative to conventional fencing. The fences have the advantage of being more effective and can be transported to other locations once the vegetation is well established. Other methods of site protection will require development. Development of protective management practices is critically important, and promises to be a most difficult research problem.

Another related problem is damage that occurs to the newly establishing vegetation by wildlife. The problems is especially frustrating, given the fact that land use objectives in these areas have been defined as developing the area for wildlife habitat. However, premature wildlife use in an area can have longterm environmental and economic consequences if not properly managed. Realizing the magnitude of the problem, the USDI Fish and Wildlife Service has established a wildlife damage control research project. The project is responsible for the following:

- To develop sound Management methods to alleviate wildlife damage to timber crops in ways that are in harmony with other environmental values. (No other Project in the Federal Government has this responsibility.

- To provide updated knowledge and techniques on

forest-animal damage control procedures to meet the needs of natural resource managers at local, regional, and national levels.

- To assemble and disseminate information on wildlife-reforestation interrelations to scientific and nonscientific communities.

- To coordinate research with other public and private agencies/organizations/individuals for efficiency and avoidance of duplication.

- To provide technical assistance on wildlife and reforestation matters to individuals, organizations, and agencies.

- To fulfill other functions of the Fish and Wildlife Service as delegated by higher authorities.

Key project work for the period of 1970 to 1982 is included as literature citations in Appendix A. Solutions developed by the Animal Damage Project are not always applicable to conditions in the study area but should provide a basis for further research.

Other management practices may be necessary to correct flaws and shortcomings of initial reclamation and/or to manipulate site development toward a desired condition over time. DePuit (1982) provided the following examples of corrective or manipulative management practices:

- Supplemental erosion control practices (e.g., follow-up mulching, surface manipulations, etc.) to correct recurring site stabilization problems.

- Maintenance fertilization to correct prolonged nutrient deficiencies.

- Application of selective herbicides to control weeds and/or influence the direction of community succession.

- Supplemental interseeding or transplanting to address initial revegetation failures and/or increase diversity.

- For domestic livestock, implementation of various controlled grazing systems to influence the rate and

direction of community development.

Information on application of these and other corrective or manipulative practices is very limited for disturbed lands in general, and is non-existent for oil and gas disturbances within the study area. Considerable future research emphasis is thus warranted.

SUMMARY

The preceding sections have attempted to briefly describe principles, approaches and methods for disturbed land reclamation developed under environmental conditions similar to the Bear River Divide/Overthrust Belt study area, as detailed descriptions of methods were not possible within the scope of this report. It is believed that many of the general reclamation principles and practices so described may be directly applied or applied with appropriate modifications to oil and gas disturbances in the study area. Existent technology appears to be most adequate in the areas of topsoiling, site stabilization and moisture conservation, and revegetation with perennial grasses. Existing technology appears to be least sufficient in the following areas:

- Integrated, area-wide planning to optimize relationships between onsite reclamation and surrounding land conditions for support of desired land uses.
- Regrading practices to promote concurrent achievement of multiple land use goals while still providing for adequate site stability.
- Proper plant species selection and mixtures specifically tailored to conditions and land use needs within the study area.
- Successful methods for shrub, tree and forb revegetation within the study area.
- Successful methods for establishment of requisite intra- and inter-plant community diversity.
- All classes of management practices for sites after initial reclamation, but most notably protective practices.

All of the above areas have significance in terms of wildlife habitat reestablishment on sites disturbed by oil and gas development within the study area, and therefore deserve future research emphasis.

ECONOMIC CONSIDERATIONS

Costs for reclamation vary widely from site to site (Leathers 1980; Grim and Hill 1974). Leathers (1980) indicated that 90% of the reclamation costs on Wyoming strip mines was attributed to earth moving costs. Although less earth moving is necessary for oil and gas development, unlike strip mining, soil removal is not necessary for ore retrieval, consequently most earth moving costs must be charged to reclamation (Pensse et al. 1977). Since earth moving costs are the largest component of reclamation costs, factors that influence the amount and nature of topsoil stripping, replacement, distance of haul and the degree of backfilling and grading required will greatly affect the total cost of reclamation. Drier, harsher and more remote sites often require unique reclamation practices and standard reclamation practices are more difficult to implement. Therefore, reclamation costs increase on these harsher sites (Leathers 1980). Costs taken from data in 1983 annual reports to the Wyoming Department of Environmental Quality (WDEQ) from several western Wyoming mines indicate topsoiling costs ranging from $780-$2982/acre and revegetation costs ranging from $580-$1601/acre. Leathers (1980) estimated revegetation costs in 1976 to range from $130-$275/acre, an indication that costs have risen 4 to 6 times over a 7 year period. This is a reflection on the implementation of the Surface Mining Control and Reclamation Act and it's more stringent requirements coupled with inflation.

Costs that are fairly typical for the type of reclamation occurring in the Overthrust Belt were compiled from the published literature (Kerr Associates Inc 1983; Robert Snow Means Company Inc 1984) and modified from personal contact with operators, contractors, and government agencies (Table 1). These costs are necessarily general and should be used as a guide to assess the cost of a technique relative to another technique. Reclamation procedures which are apt to be most commonly used have been selected. Costs for each technique vary widely depending on a number of factors and the costs reported here are ranges of fairly typical costs. General factors that may influence costs include size and contiguous nature of the disturbance, ease of access, type of equipment used, remoteness, steepness of slope, timing constraints, weather conditions, unique implementations or modifications of standard techniques and reliability and performance quality of the contractor.

Reclamation on contiguous areas can be implemented more rapidly than on small, broken or intermittent areas, thus operating expenses and labor cost on a per unit basis are reduced. Different equipment, capable of accomplishing similar tasks, function with varying degrees of efficiency under different conditions. In addition, equipment often differs in purchase price and in operation, maintenance and mobilization costs. For example, scrapers can generally move topsoil cheaper than dozers, but they have higher mobilization costs. Skelly and Loy (1975) indicated that the major factor affecting

haulage cost is distance. They stated that dozers and loaders are only economical for haulage distances ranging from 100 to 200 feet, and 200 to 500 feet respectively. For distances greater than 500 feet costs increase rapidly. As haulage increases to 700 feet and higher, trucks or scrapers become more economical. The cost of using scrapers is less than trucks for distances between 700 to 1300 feet and relatively similar for distances greater than 1300 feet. However, scrapers may be temporarily unavailable for a job and as a result higher dozer costs may be necessary.

Equipment may also affect the cost of seeding. Seeding with clean, large seed may be accomplished cheaper by a less expensive farm grain drill, but trashy or variable-sized seed may require a more expensive Brillion or rangeland drill with seed pickers and multiple seed boxes. Often, factors such as ease of access, slope steepness, weather conditions or unique implementation of reclamation procedures not only delay the reclamation process, thus increasing operating and labor costs, but may necessitate special adapted equipment which also increases the cost. Leathers (1980) indicated that reseeding in years of abnormally low rainfall (sometimes as often as every third year) could increase the cost by one-third or more. Volume purchases and availability of materials can influence costs. Other specific factors influencing costs have been noted in Table 1. It should be noted that these influencing factors may result in costs occurring outside the ranges listed in Table 1.

Table 1. Ranges of costs and major factors influencing cost often incurred for common revegetation practices. The most typical costs are enclosed in paratheses. All costs are in 1984 U.S. dollars.

TECHNIQUE	RATE	MAJOR INFLUENCING FACTORS
Site Preparation		
Brush removal (small-med shrubs)	75-200/a	Density and size of woody plants
Topsoil removal and stockpiling (<1/5 mi. haul)	.65-2.5/yd^3 (.9-1.2/yd^3)	Depth of topsoil, distance of haul, equipment used
Ripping	30-170/a	Depth of ripping, substrate
Topsoil replacement of grading (<1/5 mi haul)	.80-3.00/yd^3 (1.0-1.5/yd^3)	Depth of topsoil, distance of haul, equipment used
Disking	25-50/a (35)	Depth of disking, substrate
Harrowing	20-50a (30)	Substrate
Clod busting	100-150a (125)	Substrate, length of slope
Soil Amendments		
Broadcast	25-60/a (35)	
Fertilizer		
Ammonium nitrate (34-0-0)	.15-.20/lb	
Ammonium phosphate (16-20-0)	.15-.20/lb	
Tablet (20-10-5)	.08/ea	
Seeding		
Broadcast	20-60/a (35)	
Drill seed	30-130/a (75)	Amount of trashy seed
Hydro seed	30-160/a	Distance to water
Grass seed (PLS lb)	.90-40/lb (1.5-9/lb)	Species
Forb seed (PLS lb)	.70-50/lb	Species
Shrub seed (PLS lb)	6-110/lb	Species
Planting		
Planting	.30-1.0/ea	Substrate, plant material
Bareroot	.15-.50/ea	Size of plant
Container (tubeling)	.60-.95/ea	Size of plant
Mulching		
Straw/hay blowing	75-100/a (80/a)	Wind, length of slope
Crimping	25-45/a	
Hydromulching	50-130/a	Distance to water
Jute application	900-1800/a	Length of slope
Excelsior application	900-1800/a	Length of slope
Plastic mesh application	800/a	Length of slope
Straw	50-90/T (60)	Quality, freight, handling
Hay	60-100/T (75)	Quality, freight, handling

Table 1. Continued

TECHNIQUE	RATE	MAJOR INFLUENCING FACTORS
Mulching (Continued)		
Excelsior	3300-4300/a	
Plastic mesh	2800-2900/a	
Fiber mulch w/ tackifier	1.20/lb	
Erosion Control Feature		
Diversion trench	5-7/ft.	
Riprap	16-24/yd^3	Substrate
Mobilization	80-190/ea equipment item	

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APPENDIX A - SELECTED LITERATURE REFERENCES FOR MAMMAL CONTROL

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(1970-1982)

A RESEARCH PROJECT OF THE USDI FISH AND WILDLIFE SERVICE

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APPENDIX B - COOPERATIVE WILDLIFE-PHOSPHATE STUDY
RECOMMENDATIONS FOR RECLAMATION AND HABITAT IMPROVEMENT
(Kuck 1984)

RECLAMATION

1. All sites disturbed during mining should be reclaimed to original levels of wildlife productivity and cover.

2. A regional reclamation plan should be developed.

3. Reclamation sites should be monitored to determine success or failure of reclamation efforts.

4. Reclamation of a site for both wildlife and livestock is a potential conflict. Wildlife and livestock values should be prioritized by mine sites.

5. Wildlife reclamation should receive priority on sites which originally supported aspen or conifer with high cover values, or were identified as big game winter range.

6. Reclamation of wildlife habitat should be defined in terms of cover, not just forage.

7. If and when possible, improvements of aspen stand should be considered the highest priority in wildlife habitat reclamation programs.

8. Cover reestablishment cannot be over-emphasized. A ratio of 40% cover to 60% open areas with forage is the minimum acceptable for wildlife habitat. Aspen stands can be used during most of the year as both cover and forage by big game.

9. Reclamation sites with wildlife habitat potential should be fenced from livestock to permit vegetation establishment and natural succession to more desireable cover types.

10. Topsoil should be removed and stockpiled. Topsoil should be reused as soon as possible.

11. Wildlife reclamation programs should be planned and implemented so that they may be sustained without additional manipulation, fertilization, or irrigation.

12. Less emphasis should be placed on the most rapid growth or most vigorous "green grass." Instead, reclamation should attempt to obtain a combination; of plant species which will provide a diversity of food and cover for big game and aid in natural succession of plant communities.

13. Native or acceptable non-native plant species should be used for vegetation reestablishment. Criteria for selecting species for revegetation should include plant palatability and nutritive value, and big game forage preferences and cover requirements.

14. Mixtures of plant species should be chosen to obtain a variety of forage types and a long season of availability of succulent forage.

15. Sites with low potential for cover reestablishment should be stabilized and fenced to minimize soil erosion and water quality impacts. To compensate, cost-effective off-site habitat management must be implemented to replace these non-recoverable wildlife habitat values. Treatment of aspen stands through burning, spraying or logging is suggested as the most practical method to fully compensate for mining impacts on wildlife habitat potential.

16. Cooperative programs with federal land management agencies need to be established by individual companies to participate in off-site habitat manipulation programs, i.e., aspen regeneration, to compensate for low wildlife habitat potential on reclaimed sites altered during mining.

17. Legislative action should be implemented to earmark a percentage of phosphate royalties for on- and off-site habitat restoration and mining impact mitigation.

OFF-SITE HABITAT IMPROVEMENT

1. The most important factor affecting future big game populations appears to be the natural decline in wildlife habitat productivity through natural succession from aspen to conifer habitat. This is occurring independently of mining activities.

2. We strongly advocate that an aggressive aspen regeneration program be implemented to retard the effects of succession through herbicide spraying, burning, logging, and fuelwood cutting.

3. Aspen habitat improvement is the most cost-effective and desireable method of off-site mitigation to compensate for non-recoverable wildlife habitat values lost during mine development.

4. Use of aspen for co-generation is an acceptable aspen management tool, provided the present road system is not expanded, which could compound illegal harvest and disturbance problems present on the area.

5. Productive wildlife habitat values will be maintained only if aspen stands on the study are treated more intensively than at present. We suggest

13. Herbs or acceptable non-native plant species should be used for vegetation reestablishment. Criteria for selecting species for revegetation should include plant palatability and nutritive value, and big game forage preferences and cover requirements.

14. Mixtures of plant species should be chosen to obtain a variety of forage types and a long season of availability of succulent forage.

15. Sites with low potential for cover reestablishment should be stabilized and fenced to minimize soil erosion and water quality impacts. To compensate, cost-effective off-site habitat management must be implemented to replace these non-recoverable wildlife habitat values. Treatment of aspen stands through burning, spraying or logging is suggested as the most practical method to fully compensate for mining impacts on wildlife habitat potential.

16. Cooperative programs with federal land management agencies need to be established by individual companies to participate in off-site habitat mantipulation programs, i.e., aspen regeneration, to compensate for low wildlife habitat potential on reclaimed sites altered during mining.

17. Legislative action should be implemented to require a percentage of proceeds royalties for on- and off-site habitat restoration and mining impact mitigation.

OFF-SITE HABITAT IMPROVEMENT

1. The most important factor affecting future big game populations appears to be the natural decline in wildlife habitat productivity through natural succession from aspen to conifer habitat. This is occurring independently of mining activities.

2. We strongly advocate that an aggressive aspen regeneration program be implemented to retard the effects of succession through herbicide spraying, burning, logging, and fuelwood cutting.

3. Aspen habitat improvement is the most cost-effective and mitigable method of off-site mitigation to compensate for non-recoverable wildlife habitat values lost during mine development.

4. Use of aspen for re-generation is an acceptable aspen management tool, provided the present road system is not expanded, which could compound illegal harvest and disturbance problems present on the area.

5. Productive wildlife habitat values will be maintained only if aspen stands on the study are treated more intensively than at present. We suggest

that 10% of stands be treated in every 4-year period.

6. The Caribou National Forest should develop a Forest-wide aspen managment plan.

7. Cooperative agreements between the Idaho Department of Fish and Game, U.S. Forest Service, U.S. Bureau of Land Management, and individual mining companies should be developed to defray cost of the aspen management program.

8. Knutson-Vandenberg (K-V) funds from timber sales on mine leases should be used for off-site wildlife habitat improvement near mine sites.

HABITAT RETENTION

1. The primary emphasis during mine planning and development should be directed toward minimal alteration of native vegetation and soil.

2. Backfilling practices should be utilized to reduce destruction of vegetation for external dumps, and to increase reclamation alternatives.

3. Support facilities (tipples, shops, garages, railroads, etc.) and external dumps should be placed only on sites which are already incapable of supporting important cover types, such as aspen and conifer forests.

4. Strips of native vegetation, particularly those with high cover values (aspen and conifer forests) should be retained between pits, dumps, and other support facilites and along roads. This will provide sight barriers to enhance big game use, to enhance interspersion and edge effect, and to provide a seed source for natural reclamation.

5. Mines, transportation systems, support facilities, and other auxiliary activities should be planned so as to minimize fragmentation of habitats with high big game cover values (e.g., Dry Valley aspen stand).

6. As much cover as possible should be left at the edge of the mine to provide sight barriers, to enhance utilization by big game, to increase interspersion, and to provide a seed source for natural reclamation.

7. Management of other surface resources (such as timber) should be coordinated, to ensure that cover is maintained near mines.

8. Timber harvests on proposed mine sites should be coordinated, and sequentially logged along with mine development, to minimize disturbance of wildlife.

9. Development of roads and transportation systems should be held to a

minimum.

10. Roads and other support facilities should be placed so as to avoid sensitive areas, such as big game winter ranges, elk calving areas, and deer migration routes.

11. Roads should be placed within cover types (the exceptions being sensitive areas such as calving areas and winter ranges), with as few straight stretches as possible to minimize disturbance and illegal harvest of big game, and to facilitate big game movements.

12. All access roads should be designed to facilitate closure at the end of mine development.

13. Revision of mine leasing laws should be advocated to permit the sequential development of mine sites in a logical pattern, to maintain disturbance in a "predictable" area, and to preserve undeveloped habitats as long as possible.

APPENDIX C - ARANDONED DRILL SITE STUDY
RECOMMENDAddONS FOR RECLAMATION AND RESEARCH
(Waldvogel 1984)

IMPROVED APPLIED RECLAMATION PRACTICES

Results of this study, with subsequent interpretation, have made it possible to suggest several potentially beneficial procedures for current and future reclamation activities for oil and gas disturbances within the Briger-Teton National Forest or other similar ecosystems. These are:

1. The drill site should be regraded to a slope that will prevent soil erosion and promote vegetation establishment. This slope should resemble the original contour, or in cases where the original slope was overly steep or erosive the new grade must meet more acceptable standards of functioning with the surrounding undisturbed topography.

2. Recontoured sites should be ripped to alleviate subsoil compaction.

3. Topsoil should be removed and stockpiled prior to drilling and subsequently reapplied to the recontoured site after abandonment. This topsoiled surface should also be ripped, chiseled and/or harrowed to alleviate the compaction resulting from the machinery required for topsoil reapplication.

4. The seed mixture to be used must be designed to guarantee that a stand of vegetation will be present the first growing season in order to stabilize and protect the soil resource and add organic matter to the soil.

5. In addition to being rapidly establishable, plant species selected for seeding should be adapted to the site, irrespective of origin (e.g., native or introduced), in terms of utility and autecological characteristics. Synecological compatability is essential if accelerated successional development is desired. Seeding overly competitive and/or longevous species may be inappropriate. Initial seeding of later seral stage species may be ill advised except for species exhibiting wide seral amplitude (i.e., components of both early and later successional seres). Later-seral stage species which are difficult to initially establish may possibly be interseeded or transplanted following initial site revegetation. Seed or transplants of species selected for revegetation must also be practically available.

6. Within the sagebrush vegetation type, Agropyron trachycaulum may be a widely adapted native species. Deschampsia caespitosa, Hordeum brachyantherum and Festuca idahoensis may be adapted to upper elevation disturbances. Hesperachloa kingii appeared to be especially adapted to rocky sites. The native forb species Achillea millefolium, Aster chilensis and Taraxacum officinale exhibited wide adaptational amplitude and may be adapted to most disturbances. Bromus inermis was a widely adapted introduced grass species

found on most of the sites sampled, and this could offer utility on a variety of disturbances. Shrubs can be expected to reestablish naturally, albeit slowly, within seeded vegetation. If it is desired to restore these species more rapidly, shrub establishment via various transplanting methods should be considered.

7. Within the coniferous vegetation type, it will be necessary to transplant coniferous species in conjunction with grasses and forbs to accelerate reforestation, if this is the desired goal. Pinus contorta would probably be the most successful tree species to initially plant due to its ability to grow in full sunlight. It's presence may then later provide a suitable environment for shade tolerant late seral tree, shrub and forb species. However, grass species will usually be necessary as initial site colonizer/stabilizers (i.e., pioneer, early seral species) on disturbed coniferous sites. Adapted beneficial species include Bromus inermis, Agropyron intermedium, Dactylis glomerata, and Poa pratensis. Forb species noted to be initially adapted to the coniferous disturbances were Taraxacum officinale, Achilleamillefolium, Antennaria microphylla, and Trifolium pratense.

8. On sites where slopes are excessively steep or soils are unusually unstable, rocky and/or low in organic matter, or where prevailing climatic conditions may pose a threat to seedling establishment, an organic mulch material should be applied after seeding to hold the soil in place, conserve water and add organic matter to the soil.

9. Disturbed site soils generally were not deficient in nutrients phosphorus or potassium. However, levels of nitrogen were not determined during analysis; the possibility exists that this nutrient could be in short supply on some soils. The application of fertilizer at the time of seeding could alleviate any existing nutrient deficiencies or enhance plant growth on severely disturbed sites with limited quantities of topsoil material.

10. If reclamation success is to be evaluated in terms of vegetation resemblance to or trend toward native condition, disturbed-native site similarity indices may be the best primary parameter to use. Such indices could be used in conjunction with other information (e.g., absolute cover and/or biomass, diversity, etc.) collected on both sites to assess the overall status of plant community development.

FUTURE RESEARCH AND DEVELOPMENT

Further insight could be gained by observing and sampling soils and vegetation on the sites studied during this project in the future. The development of each individual site could then be directly ascertained, and the effects of seeding, time and other factors could be more concretely determined. Reference photos taken throughout this study should be utilized to, at least visually, assess changes in vegetation distribution and density.

There is a notable lack of available information concerning specific reclamation methods and seeded species which have proven successful on oil and gas related disturbances. Due to this, it is recommended that research be implemented to test the success of various species and reclamtion techniques on disturbances located within the soil, vegetation and elevational ranges impacted most by drilling. Results of such research would enable concrete, data-based prescriptions on reclamation methods to be drawn, rather than the solely inference-based recommendations that were possible from the present study.

APPENDIX D - SELECTED LITERATURE REFERENCES FOR MANAGEMENT OF BLOWING SNOW

Reference List for Snow Management on the Plains

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Willis, W. O., C. W. Carlson, J. Alessi, and R. J. Haas. 1961. Depth of freezing and thawing [illegible] related to soil moisture level. Canadian J. Soil Sci. 41:115-123.

Willis, W. O., H. L. Parkinson, C. W. Carlson, and H. J. Haas. 1964. Water table changes and soil moisture loss under frozen conditions. Soil Sci. 98(4):244-248.

Willis, W. O., A. B. Frank, E. J. George, and H. J. Haas. 1976. Soil water extraction by, and growth of, multi-row windbreaks. Proc. Shelterbelts on the Great Plains. Great Plains Agr. Council Pub. No. 78:87-92.

Woodruff, N. P. 1954. Shelterbelt and surface barrier effects on wind velocities, evaporation, house heating, snow drifting. Kansas Agric. Exp. Stn. Tech. Bull. 77, Kansas State College, Manhattan, Kansas.

Woodruff, N. P., L. Lyles, F. H. Siddoway and D. W. Fryrear. 1977. How to control wind erosion. U. S. Dept. Agric., Agric. Info. Bull. No. 345. 23 pp.

Wrubleski, P. D., G. E. Frehlich and J. D. Wassermann. 1981. Straight combining and drying - an alternative to windrowing. In, Proc. Soils and Crops Workshop, Div. of Extension and Community Relations, Publ. No. 454, pp. 121-138.

Ylimaki, A. 1962. The effect of snow cover on temperature conditions in the soil and overwintering of field crops. Annales Agriculturae Fenniae, 1:192-216 (Seria Phytopathologia N. 3 - Sarja Kasvitaudit n:o 3)

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APPENDIX E - SELECTED LITERATURE REFERENCES FOR REHABILITATION OF RIPARIAN HABITATS

TIMBERLINE RECLAMATION, INC., BOZEMAN, MONTANA

PREVENTATIVE SECTION
ROAD AND CULVERT CONSTRUCTION AND SEDIMENT CONTROL

Apmann, R.P. and M.B. Otis. 1955. Sedimentation and Stream Improvement. New York Fish and Game J. 12 (2): 117-126.

Bachman, R. 1958. The ecology of four north Idaho trout streams with reference to the influence of forest road construction. M.S. Thesis, University Idaho, Moscow. 97 pp.

Brown, R.J. and J. Mickey Jr., 1974. Stabilization of erosion on a mountainous road construction project. Pages 87-92 in Proceedings of a symposium on trout habitat research and management, U.S. Forest Service, Southeast. Forest Exp. Sta., Asheville, N.C.

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Larse, R.W. 1971. Prevention and control of erosion and stream sedimentation from forest roads. Pages 76-83 in J.T. Krygier and J.D. Hall, Directors, Proc. Symp. Forest Land Uses and Stream Environ., Oregon State University, Corvallis.

Moore, C.M., W.J. Wood, and G.W. Renfro. 1960. Trap efficiency of reservoirs, debris basins, and debris dams. American Society of Civil Engineers, Hydraulics Division Journal 86:69-87.

Tobiaski, R.A. and N.R. Tripp. 1961. Gabions for stream and erosion control. J. Soil Water Conserv. 16(16): 284-285.

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MITIGATIVE SECTION
HABITAT REHABILITATION AND ENHANCEMENT

SPAWNING

Mih, W.C., G.C. Bailey. 1981. The development of a machine for the restoration of stream gravel for spawning and rearing of salmon. Fisheries. Vol. 6, No. 6. 16-20 pp.

REARING

Archer, D.L. 1972. Fisheries investigations in lakes and streams: Evaluation of stream improvement work. Fed. Aid Proj. F-010-R-07, Job D. South Carolina Wildlife Resource Dept., Columbia. 15 pp.

Babcock, W.H. 1982. Ten Mile Creek - a study of stream relocation. Col. Div. of Wildlife Fisheries Research Station, Special Report #52, 22 pp.

Five year study involving three miles of stream relocated to facilitate construction of I-70 through Ten Mile Canyon west of Denver. The project was designed to provide fish habitat of equal value to that present before construction, and if possible, to improve the habitat. Despite a devastating flood two years after construction, population estimates indicated an increase in the number of fish in the post-construction period compared to pre-construction numbers. Fish biomass estimates for the area were comparable for the two periods.

Bailey, R. U.S. Forest Service, Six Rivers Nat. Forest, In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Ten gabion weirs, two rock weirs, and three gabion deflectors were placed in Patrick Creek, Smith River drainage, from 1979 through 1981. Pre-project monitoring observed two salmon redds and numerous female carcasses still containing eggs. Following construction, salmon populations have increased 35-40 pair, annually.

Bailey, R. U.S. Forest Service, Six Rivers Nat. Forest, In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Bailey, R. U.S. Forest Service, Six Rivers Nat. Forest, In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Ten gabion weirs, two rock weirs, and three gabion deflectors were placed in Prairie Creek, South Fork River drainage, from 1979 through 1981. Pre-project monitoring observed two salmon redds and numerous female carcasses still containing eggs. Following construction, salmon populations have increased 15-40 pair, annually.

One gabion weir and large boulders were placed in a 100 foot section of Red Cap Creek, Klamath River drainage, in 1979. Numbers of yearling steelhead increased fourfold in the boulder-treated area versus the control reach. Boulder clusters doubled instream shelter volume.

Barton, J.R., and P.V. Winger. 1973. Rehabilitation of a channelized river in Utah. Proceedings of the 21st Annual Hydraulics Div. Specialty Conference, ASCE, Montana State Univ., Bozeman, Montana. August 15-17, pp. 1-11.

Installation of a variety of gabions, check dams, deflectors, and boulders succeeded in increasing populations of six fish species within one year to levels equivalent with natural sections.

Bryant, M.D. 1983. The Role and Management of Woody Debris in West Coast Salmonid Nursery Streams. North American Journal of Fisheries Management. 3:322-330.

Claire, E. Oregon Department of Fish and Wildlife. In: Proceedings of Fish Habitat Improvement Workshop, Ochoco Ranger Station. September 26-27, 1978.

Eighteen miles of the South Fork of the John Day River were rehabilitated with riprap, groins, and boulder clusters. Fish sampling in 1/3 mile sections of the project over a two year period revealed that the only trout in the improved sections were associated with the boulders and other rock work.

Ehlers, R. 1956. An evaluation of stream improvement devices constructed 18 years ago. Calif. Fish and Game 42(3):203-217.

Article examines use and function of a variety of instream flow devices. Photographic record provided. Suggestions in structure selection and placement are given.

Gard, R. Creation of trout habitat by constructing small dams. J. Wild. Manage. 25:384-390.

A four-year study on instream improvement for the upper sections of Sagahen Creek, California. The stream gradient study section was 270 ft/mile. Brook trout survived, grew rapidly, and reproduced after improvements were made. Suggests similar improvement be carried out on other Sierra Nevada streams.

Hale, J.G. 1969. An evaluation of trout stream habitat improvement in a north shore tributary of Lake Superior. Minnesota Fisheries Investigations #5, pp. 37-50.

Effects of artificial deflectors and shelters in 1584 meters of the West Branch of Split Rock River, a Minnesota brook trout stream, were studied over a ten year period: three years before, four years during, and three years after habitat improvement. The results show a 60% increase in gravel, 894% increase in young of the year, and 223% increase in older trout. Total standing crop was up 356% as compared to the control area which increased only 65%.

Hall, J.D., and C.D. Baker. 1982. Influence of forest and rangeland management on anadromous fish habitat in western North America: 12. Rehabilitating and enhancing stream habitat: 1. Review and evaluation. Meeham, W.R., tech. ed. Gen Tech. Rep. PNW-138. Portland, Oregon, U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station. 29 pp.

Review and evaluation of previous efforts in habitat enhancement. Major emphasis is on techniques useful on West Coast streams and beneficial for anadromous fishes. The authors reviewed various aspects of gravel restoration, barrier removal, fishway development, boulder placement, and stream fertilization. Despite the failures, some gabion installations have provided useful habitat enhancement. An example used was 10 gabion dams constructed on John Creek, a tributary to the Hamma Hamma River, Washington, which drops 3.05 meters per 222 meters. These structures were successful in retaining gravels and providing a suitable gradient for spawning.

Haugen, G. U.S. Forest Service, Portland, Oregon. In: Proceedings of Fish Habitat Improvement Workshop, Ochoco Ranger Station. September 26-27, 1978.

Rock clusters with associated attached logs and rock groins and riprap were placed in the Keough River, British Columbia. A twentyfold increase in coho salmon numbers in rock cluster areas was noted the first year. Steelhead numbers increased sevenfold, associated with the rock riprap and groins.

Horner, Richard R., and E.B. Welch. 1982. Impacts of channel reconstruction in the Pilchuck River. Washington State Department of Transportation, Highway Runoff Water Quality Research Project. Report No. 15, 34 pp.

A portion of the Pilchuck River, near Snohomish, Washington, was relocated to remove it from the planned right-of-way of

Highway SR2. This five year study was conducted to compare conditions before and after channel reconstruction. The study analyzed sediment-particle size, benthic macroinvertebrates, and fish. The results gave no indications of deterioration in diversity, quantity, or size of fish in the reconstructed channel.

Hunt, R.L. 1969. Effects of habitat alteration on production, standing crops, and yield of brook trout in Lawrence Creek, Wisconsin. In: Symposium on Salmon and Trout in Streams, ed. by T.G. Northcote, Vancouver, Canada, Univ. of British Columbia, February 22-24, pp. 281-312.

The upper mile of Lawrence Creek was intensively altered by the addition of bank covers and current deflectors during 1964. These alterations reduced the surface area by 50% and increased the average depth by 60%, increased pools by 52%, and increased permanent overhanging cover for trout by 416%. Sand substrate was reduced 40%, silty bottom reduced 70%, and gravel increased by 11%. The average number of legal sized trout present when fishing season began increased by 156%, annual production increased by 17%, the mean standing crop of trout increased 40%. Food consumption increased by 28%.

_____ 1971. Responses of a brook trout population to habitat development in Lawrence Creek. Wisconsin Dept. Nat. Resour., Tech. Bull. 48. 35 pp.

_____ 1976. Instream improvement of trout habitat. Pages 26-31 In: Stream Management of Salmonids. Supplement to the Winter 1976 edition of Trout.

_____ 1976. A long-term evaluation of trout habitat development and its relation to improving management-related research. Trans. Am. Fish. Soc. 105(3):361-364.

The study on Lawrence Creek continues, with data on fish populations abundance, biomass, and production over a period of 11 years. The mean annual biomass of trout, the mean annual number of legal-sized trout, and the annual production increased significantly during the three years of project construction. Improvement continued with the maximum number of trout and the maximum trout biomass occurring five years after construction.

Hunt, W.A., and R.J. Graham. 1972. Preliminary evaluation of channel changes designed to restore fish habitat. Dept. of Civil Engineering and Engineering Mechanics, Montana State Univ., Bozeman, Montana. 72 pp.

Two artificial meanders were constructed on the Clark Fork River to maintain channel length associated with the

construction of I-90. The stream has a slope of 10 ft/mile and is limited in its lateral movement by steep valley side slopes. Random boulder placement was used for fish habitat. Results show the hydraulic, topographic, and fish populations in the reaches to be comparable to natural sections of the river.

Hunter, G.W., L.M. Thorpe, and D.E. Grosvenor. 1940. An attempt to evaluate the effect of stream improvements in Connecticut. Trans. 5th N. Amer. Wildlife Conf. 276-291.

The work was performed on the Blackledge River, formerly noted as a fine trout stream. A reach deficient in pools, riffles, and gravels was selected to test the effectiveness of a "V" dam. The dam created a quiet water pool 1.5 feet deep upstream and provided increased bank cover and 100% water turnover every 50 seconds. Below the dam, the pool created was 50 feet long with a maximum depth of 6.5 feet. The results showed an increase in both trout and important trout-food organisms.

Johnson, M.O. Antigo area, Wisconsin. In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

In the Plover River, 25 combination wing deflectors-boom covers were placed in a 3,000 foot section during 1973 and 1974. An attempt was made to increase the percentage of fish 8" and up. Between 1974 and 1980, a 44% increase was shown in biomass of brown trout, and brook trout biomass dropped 15%. A major increase occurred in 10" brown trout, while 14" brown trout went from 0 to 32.1 lbs. per mile. Other improved streams also showed increases in trout biomass and numbers.

Lere, Mark Edmond. 1982. The long-term effectiveness of three types of stream improvement structures installed in Montana streams. MS Thesis, Montana State Univ., Bozeman, Montana. 99 pp.

The long-term effectiveness and durability of random boulders, rock jetties, and log step dams installed as improvement structures were evaluated in 1979 and 1980. Random boulders and rock jetties placed in channelized sections of the St. Regis River appeared to have restored habitat for cutthroat trout (Salmo clarki) and brook trout (Salvelinus fontinalis) populations. Total numbers of trout were least in partially altered control, greatest in a section mitigated with random boulders and intermediate in a section mitigated with rock jetties.

MacCaferri Gabions of America. 1966. Stream improvement handbook. MacCaferri Gabions of America, Inc., Flushing, New York. 15 pp.

Maughan, Eugene O., and K.L. Nelson. 1980. Improving stream fisheries. Water Spectrum 12(2):10-15.

Four streams in the Virginia mountains were studied to evaluate the effectiveness of various structures. The streams were characterized by steep gradients, rapid runoff, and periodic flooding. The structures consisted of log dams, rock-filled gabions, and random boulder placement.

In two of the streams in which log dams were used, the biomass of the trout collected was greater than in unimproved sections. Although no statistically significant differences in total trout biomass were found between unimproved sections and sections with boulder placement, the use of the boulders by trout was apparent during electroshocking.

Michigan Stream Improvement Program - Selected Evaluations. In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Review of four projects performed by various agencies in the state. In Fishdam River, stream habitat enhancement resulted in the maintenance of a sport fishery with wild stock, replacing annual plantings of 10,000 to 15,000 yearling brown and brook trout.

Reeves, G.H., and T.D. Roelofs. 1982. Influence of forest and rangeland management on anadromous fish habitat in western North America: 13. Rehabilitating and enhancing stream habitat: 2. Field applications. Meehan, W.R., tech ed. Gen Tech. Report, PNW-140. Portland, Oregon, U.S.D.A., Forest Service, Pacific Northwest Forest and Range Experiment Station. 38 pp.

This paper describes techniques for habitat enhancement as it pertains to west coast streams and anadromous fish. Current projects on the west coast were personally assessed by the authors while preparing this report.

Rinne, John N., and J. Stefferud. Stream Habitat Improvement in Southwestern United States, Arizona and New Mexico. In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Descriptions of four habitat improvement projects in Arizona and New Mexico showed that increased habitat over 137 km (60

different streams) allowed the stocking of an additional 34,200 rainbow trout and increased angler catch rate by 0.10 fish per manhour.

Saunders, J.W., and M.W. Smith. 1962. Physical alteration of stream habitat to improve brook trout production. Trans. Am. Fish. Soc. 91(2):185-188.

Stream improvements were done on three different habitat types (pools, flat water, and riffles) within the stream. With the exception of the wire and nails used in construction, all materials used were from the immediate riparian area. Log dams, wing deflectors, and overhanging cover were constructed. In the year following reconstruction, the standing crop of fingerlings (age 0) was above average. The numbers of age 1 and older trout were doubled.

Shaw, M.A. Wasatch-Cache National Forest. In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Temple Fork Creek, Logan River drainage, has undergone stream habitat enhancement since the 1930's. In 1963, three log K-dams and three double-log wing deflectors were installed. Fish populations (brown, cutthroat, and rainbow) increased by 100%.

Shetter, D.S., O.H. Clark, and A.S. Hazzard. 1946. The effects of deflectors in a section of a Michigan trout stream. Trans. Am. Fish. Soc. 76:248-278.

Installation of 24 pool-forming deflectors raised the number of good pools from 9 to 29, increased average pool depth by 6 inches, and exposed additional gravel downstream of structures, significantly changing the average stream depth. Brook trout populations increased 120% and it was demonstrated that migration into the section was improved but was not responsible for the increase. Also, bordering sections failed to have fish populations comparable to the improved section.

Smith, B.R. 1981. Thomas Fork cooperative aquatic habitat management plan, progress report. Bureau of Land Management, Rock Springs District, Kemmerer Area, USDA, 23 pp.

Article outlines efforts to improve habitat for Utah cutthroat trout (Salmo clarki), previously believed to be extinct in its true unhybridized form. Four years after initial improvements, there has been a 25% increase in total

fisheries biomass and a 70% increase in trout biomass. This corresponds to an 83% increase in numbers of trout per mile. In addition, two new species have moved into the study area (whitefish and mountain suckers). These increases have occurred despite an increase in fishing pressure.

Stream Improvement Projects in Wyoming. In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Brief descriptions of 20 stream improvement projects in Wyoming. One documented improvement was given for work done by Wyoming Game and Fish Departments on Three Channel Spring Creek, Teton County. In this project spawning riffles were rejuvenated by removing compacted cobble, adding gravel, and placing large snags as cover. Cutthroat spawning activity increased from 70 redds/year in 1970-71 to 225 redds/year by 1980.

Stream Renovation Guidelines Committee. 1983. Stream obstruction removal guidelines. American Fisheries Society and Wildlife Society.

Tarzwell, C.M. 1936. Experimental evidence on the value of trout stream improvement in Michigan. Trans. Am. Fish. Soc. 66:177-187.

Methods are developed for the improvement of trout streams and then tested and shown to be most effective in producing positive changes in overall productivity, especially in bottom pool and shallow riffle faunas.

Tarzwell, C.M. 1938. An evaluation of methods and results of stream improvements in the S.W. Trans. 3rd N. Amer. Wildlife Conf. pp. 339-367.

Compared an improved stream (Horton Creek) with an unimproved stream (Upper Tonto Creek). It was shown that even though Upper Tonto received nearly twice as many stocked fish as Horton, the total fish yield from Horton was greater each year. It also appeared that the improvements increased the natural reproduction as evidenced by the greater number of young trout in Horton Creek.

Todd, D.J. 1972. Effects of low gabion dams on primary production in high altitude streams. J. Colorado-Wyoming Acad. Sci. 7(2-3): 86.

Wydoski, R.S., and D.A. Duff. 1982. Indexed bibliography on stream habitat improvement (revised). U.S.D.A. Forest Service, Intermountain Expt. Sta., Ogden, Utah. 143 pp.

A review and discussion of the varying types of stream habitat improvement as it relates to the Intermountain West. Duff found that properly constructed instream structures in desert mountain ranges within the great basin can benefit rare native salmonid species even in high gradient streams that are subject to high fluctuations in runoff. Increases in trout populations were shown to accompany stream habitat improvement. Increases ranged from 143% in a midwest stream to 243% and 128% in two Intermountain West streams.

RIPARIAN

American Fisheries Society, Western Division. 1982. The best management practices for the management and protection of western riparian stream ecosystems. Riparian Habitat Committee.

Brazier, J.R. and G.W. Brown. 1973. Buffer strips for stream temperature control. School Forest., Oregon State University, Corvallis. Res. Pap. 15. 9 pp.

Claire, E. Oregon Department of Fish and Wildlife. In: Proceedings of Fish Habitat Improvement Workshop, Ochoco Ranger Station. September 26-27, 1978.

A six mile section of Camp Creek, Middle Fork John Day drainage, was fenced in 1976 to exclude cattle grazing from a historically heavily-grazed area. A 21-year record of steelhead spawning surveys show that in recent years there has been a redd count of 16.9 per mile outside of the area and 30.0 inside. A four year average of samples inside the area show 415 juvenile steelhead and 208 outside. Dace populations were the reverse. There were 93 inside and 663 outside. There were no juvenile dace in the protected area and few "0" age steelhead outside.

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Dove, J.L. 1974. State of the art in design of sediment control structures. Am. Soc. Agr. Eng., Pap. 74-2570. 9 pp.

Dryden, R.L. and J.N. Stein. 1975. Guidelines for the protection of the fish resources of the Northwest Territories during highway construction and operation. Canadian Dep. Environment, Fish. and Marine Serv., Tech. Rep. Series No. CEN/T-75-1. 32 pp.

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Hansen, E.A. 1968. Stabilizing eroding stream banks. U.S. Dep. Agri., Forest Serv., Res. Pap. NC-21. 12 pp.

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Bachman, R. 1978. The ecology of four north Idaho trout streams with reference to the influence of forest road construction. M.S. Thesis, University Idaho, Moscow. 97 pp.

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Claire, S. Oregon Department of Fish and Wildlife, [illegible]: Proceeding of Fish Habitat Improvement Workshop, Oakridge Ranger Station. September 26-27, 1978.

Log step dams were placed in Deadfort Creek, John Day River drainage, to improve passage through a culvert. Fish sampling in the ponds revealed that there were five times as many fish there as in an adjacent area without benefit of such structures.

Dane, B.G. 1978. A review and resolution of fish passage problems at culvert sites in British Columbia. Fisheries and Marine Service, Tech. Rep. No. 810, 124 pp.

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Archer, D.L. 1972. Fisheries investigations in lakes and streams: Evaluation of stream improvement work. Fed. Aid Proj. F-010-R-07, Job D. South Carolina Wildlife Resource Dept., Columbia. 15 pp.

Babcock, W.H. 1982. Ten Mile Creek - a study of stream relocation. Col. Div. of Wildlife Fisheries Research Station, Special Report #52, 22 pp.

Five year study involving three miles of stream relocated to facilitate construction of I-70 through Ten Mile Canyon west of Denver. The project was designed to provide fish habitat of equal value to that present before construction, and if possible, to improve the habitat. Despite a devastating flood two years after construction, population estimates indicated an increase in the number of fish in the post-construction period compared to pre-construction numbers. Fish biomass estimates for the area were comparable for the two periods.

Bailey, R. U.S. Forest Service, Six Rivers Nat. Forest, In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Ten gabion weirs, two rock weirs, and three gabion deflectors were placed in Patrick Creek, Smith River drainage, from 1979 through 1981. Pre-project monitoring observed two salmon redds and numerous female carcasses still containing eggs. Following construction, salmon populations have increased 35-40 pair, annually.

Bailey, R. U.S. Forest Service, Six Rivers Nat. Forest, In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

One gabion weir and large boulders were placed in a 100 foot section of Red Cap Creek, Klamath River drainage, in 1979. Numbers of yearling steelhead increased fourfold in the boulder-treated area versus the control reach. Boulder clusters doubled instream shelter volume.

Barton, J.R., and P.V. Winger. 1973. Rehabilitation of a channelized river in Utah. Proceedings of the 21st Annual Hydraulics Div. Specialty Conference, ASCE, Montana State Univ., Bozeman, Montana. August 15-17, pp. 1-11.

Installation of a variety of gabions, check dams, deflectors, and boulders succeeded in increasing populations of six fish species within one year to levels equivalent with natural sections.

Bryant, M.D. 1983. The Role and Management of Woody Debris in West Coast Salmonid Nursery Streams. North American Journal of Fisheries Management. 3:322-330.

Claire, E. Oregon Department of Fish and Wildlife. In: Proceedings of Fish Habitat Improvement Workshop, Ochoco Ranger Station. September 26-27, 1978.

Eighteen miles of the South Fork of the John Day River were rehabilitated with riprap, groins, and boulder clusters. Fish sampling in 1/3 mile sections of the project over a two year period revealed that the only trout in the improved sections were associated with the boulders and other rock work.

Ehlers, R. 1956. An evaluation of stream improvement devices constructed 18 years ago. Calif. Fish and Game 42(3):203-217.

Article examines use and function of a variety of instream flow devices. Photographic record provided. Suggestions in structure selection and placement are given.

Gard, R. Creation of trout habitat by constructing small dams. J. Wild. Manage. 25:384-390.

A four-year study on instream improvement for the upper sections of Sagahen Creek, California. The stream gradient study section was 270 ft/mile. Brook trout survived, grew rapidly, and reproduced after improvements were made. Suggests similar improvement be carried out on other Sierra Nevada streams.

Hale, J.G. 1969. An evaluation of trout stream habitat improvement in a north shore tributary of Lake Superior. Minnesota Fisheries Investigations #5, pp. 37-50.

Effects of artificial deflectors and shelters in 1584 meters of the West Branch of Split Rock River, a Minnesota brook trout stream, were studied over a ten year period: three years before, four years during, and three years after habitat improvement. The results show a 60% increase in gravel, 894% increase in young of the year, and 223% increase in older trout. Total standing crop was up 356% as compared to the control area which increased only 65%.

Hall, J.D., and C.D. Baker. 1982. Influence of forest and rangeland management on anadromous fish habitat in western North America: 12. Rehabilitating and enhancing stream habitat: 1. Review and evaluation. Meeham, W.R., tech. ed. Gen Tech. Rep. PNW-138. Portland, Oregon, U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station. 29 pp.

Review and evaluation of previous efforts in habitat enhancement. Major emphasis is on techniques useful on West Coast streams and beneficial for anadromous fishes. The authors reviewed various aspects of gravel restoration, barrier removal, fishway development, boulder placement, and stream fertilization. Despite the failures, some gabion installations have provided useful habitat enhancement. An example used was 10 gabion dams constructed on John Creek, a tributary to the Hamma Hamma River, Washington, which drops 3.05 meters per 222 meters. These structures were successful in retaining gravels and providing a suitable gradient for spawning.

Haugen, G. U.S. Forest Service, Portland, Oregon. In: Proceedings of Fish Habitat Improvement Workshop, Ochoco Ranger Station. September 26-27, 1978.

Rock clusters with associated attached logs and rock groins and riprap were placed in the Keough River, British Columbia. A twentyfold increase in coho salmon numbers in rock cluster areas was noted the first year. Steelhead numbers increased sevenfold, associated with the rock riprap and groins.

Horner, Richard R., and E.B. Welch. 1982. Impacts of channel reconstruction in the Pilchuck River. Washington State Department of Transportation, Highway Runoff Water Quality Research Project. Report No. 15, 34 pp.

A portion of the Pilchuck River, near Snohomish, Washington, was relocated to remove it from the planned right-of-way of

Highway SR2. This five year study was conducted to compare conditions before and after channel reconstruction. The study analyzed sediment-particle size, benthic macroinvertebrates, and fish. The results gave no indications of deterioration in diversity, quantity, or size of fish in the reconstructed channel.

Hunt, R.L. 1969. Effects of habitat alteration on production, standing crops, and yield of brook trout in Lawrence Creek, Wisconsin. In: Symposium on Salmon and Trout in Streams, ed. by T.G. Northcote, Vancouver, Canada, Univ. of British Columbia, February 22-24, pp. 281-312.

The upper mile of Lawrence Creek was intensively altered by the addition of bank covers and current deflectors during 1964. These alterations reduced the surface area by 50% and increased the average depth by 60%, increased pools by 52%, and increased permanent overhanging cover for trout by 416%. Sand substrate was reduced 40%, silty bottom reduced 70%, and gravel increased by 11%. The average number of legal sized trout present when fishing season began increased by 156%, annual production increased by 17%, the mean standing crop of trout increased 40%. Food consumption increased by 28%.

_____ 1971. Responses of a brook trout population to habitat development in Lawrence Creek. Wisconsin Dept. Nat. Resour., Tech. Bull. 48. 35 pp.

_____ 1976. Instream improvement of trout habitat. Pages 26-31 In: Stream Management of Salmonids. Supplement to the Winter 1976 edition of Trout.

_____ 1976. A long-term evaluation of trout habitat development and its relation to improving management-related research. Trans. Am. Fish. Soc. 105(3):361-364.

The study on Lawrence Creek continues, with data on fish populations abundance, biomass, and production over a period of 11 years. The mean annual biomass of trout, the mean annual number of legal-sized trout, and the annual production increased significantly during the three years of project construction. Improvement continued with the maximum number of trout and the maximum trout biomass occurring five years after construction.

Hunt, W.A., and R.J. Graham. 1972. Preliminary evaluation of channel changes designed to restore fish habitat. Dept. of Civil Engineering and Engineering Mechanics, Montana State Univ., Bozeman, Montana. 72 pp.

Two artificial meanders were constructed on the Clark Fork River to maintain channel length associated with the

Highway 382. This five year study was conducted to compare conditions before and after channel reconstruction. The study analyzed sediment-particle size, benthic macroinvertebrates, and fish. The results gave no indications of deterioration in diversity, quantity, or size of fish in the reconstructed channel.

Hunt, R.L. 1969. Effects of habitat alteration on production, standing crops, and yield of brook trout in Lawrence Creek, Wisconsin. In: Symposium on Salmon and Trout in Streams, ed. by T.G. Northcote, Vancouver, Canada, Univ. of British Columbia, February 22-24, pp. 281-312.

The upper mile of Lawrence Creek was intensively altered by the addition of bank covers and current deflectors during 1954. These alterations reduced the surface area by 80% and increased the average depth by 60%, increased pools by 52%, and increased permanent overhanging cover for trout by 418%. Sand substrate was reduced 40%, silty bottom reduced 70%, and gravel increased by 11%. The average number of legal-sized trout present when fishing season began increased by 158%, annual production increased by 17%, the mean standing crop of trout increased 40%. Food consumption increased by 28%.

1971. Responses of a brook trout population to habitat development in Lawrence Creek. Wisconsin Dept. Nat. Resour., Tech. Bull. 49. 35 pp.

1976. Long-term improvement of trout habitat. Pages 22-31 In: Stream Management of Salmonids. Supplement to the Winter 1976 edition of Trout.

1976. A long-term evaluation of trout habitat development and its relation to improving management-related research. Trans. Am. Fish. Soc. 105(3):361-364.

The study on Lawrence Creek continues, with data on fish populations abundance, biomass, and production over a period of 11 years. The mean annual biomass of trout, the mean annual number of legal-sized trout, and the annual production increased significantly during the three years of project construction. Improvement continued with the maximum number of trout and the maximum trout biomass occurring five years after construction.

Hunt, W.A., and R.J. Graham. 1972. Preliminary evaluation of channel changes designed to restore fish habitat. Dept. of Civil Engineering and Engineering Mechanics, Montana State Univ., Bozeman, Montana. 72 pp.

Two artificial meanders were constructed on the Clark Fork River to maintain channel length associated with the

construction of I-90. The stream has a slope of 10 ft/mile and is limited in its lateral movement by steep valley side slopes. Random boulder placement was used for fish habitat. Results show the hydraulic, topographic, and fish populations in the reaches to be comparable to natural sections of the river.

Hunter, G.W., L.M. Thorpe, and D.E. Grosvenor. 1940. An attempt to evaluate the effect of stream improvements in Connecticut. Trans. 5th N. Amer. Wildlife Conf. 276-291.

The work was performed on the Blackledge River, formerly noted as a fine trout stream. A reach deficient in pools, riffles, and gravels was selected to test the effectiveness of a "V" dam. The dam created a quiet water pool 1.5 feet deep upstream and provided increased bank cover and 100% water turnover every 50 seconds. Below the dam, the pool created was 50 feet long with a maximum depth of 6.5 feet. The results showed an increase in both trout and important trout-food organisms.

Johnson, M.O. Antigo area, Wisconsin. In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

In the Plover River, 25 combination wing deflectors-boom covers were placed in a 3,000 foot section during 1973 and 1974. An attempt was made to increase the percentage of fish 8" and up. Between 1974 and 1980, a 44% increase was shown in biomass of brown trout, and brook trout biomass dropped 15%. A major increase occurred in 10" brown trout, while 14" brown trout went from 0 to 32.1 lbs. per mile. Other improved streams also showed increases in trout biomass and numbers.

Lere, Mark Edmond. 1982. The long-term effectiveness of three types of stream improvement structures installed in Montana streams. MS Thesis, Montana State Univ., Bozeman, Montana. 99 pp.

The long-term effectiveness and durability of random boulders, rock jetties, and log step dams installed as improvement structures were evaluated in 1979 and 1980. Random boulders and rock jetties placed in channelized sections of the St. Regis River appeared to have restored habitat for cutthroat trout (Salmo clarki) and brook trout (Salvelinus fontinalis) populations. Total numbers of trout were least in partially altered control, greatest in a section mitigated with random boulders and intermediate in a section mitigated with rock jetties.

MacCaferri Gabions of America. 1966. Stream improvement handbook. MacCaferri Gabions of America, Inc., Flushing, New York. 15 pp.

Maughan, Eugene O., and K.L. Nelson. 1980. Improving stream fisheries. Water Spectrum 12(2):10-15.

Four streams in the Virginia mountains were studied to evaluate the effectiveness of various structures. The streams were characterized by steep gradients, rapid runoff, and periodic flooding. The structures consisted of log dams, rock-filled gabions, and random boulder placement.

In two of the streams in which log dams were used, the biomass of the trout collected was greater than in unimproved sections. Although no statistically significant differences in total trout biomass were found between unimproved sections and sections with boulder placement, the use of the boulders by trout was apparent during electroshocking.

Michigan Stream Improvement Program - Selected Evaluations. In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Review of four projects performed by various agencies in the state. In Fishdam River, stream habitat enhancement resulted in the maintenance of a sport fishery with wild stock, replacing annual plantings of 10,000 to 15,000 yearling brown and brook trout.

Reeves, G.H., and T.D. Roelofs. 1982. Influence of forest and rangeland management on anadromous fish habitat in western North America: 13. Rehabilitating and enhancing stream habitat: 2. Field applications. Meehan, W.R., tech ed. Gen Tech. Report, PNW-140. Portland, Oregon, U.S.D.A., Forest Service, Pacific Northwest Forest and Range Experiment Station. 38 pp.

This paper describes techniques for habitat enhancement as it pertains to west coast streams and anadromous fish. Current projects on the west coast were personally assessed by the authors while preparing this report.

Rinne, John N., and J. Stefferud. Stream Habitat Improvement in Southwestern United States, Arizona and New Mexico. In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Descriptions of four habitat improvement projects in Arizona and New Mexico showed that increased habitat over 137 km (60

different streams) allowed the stocking of an additional 34,200 rainbow trout and increased angler catch rate by 0.10 fish per manhour.

Saunders, J.W., and M.W. Smith. 1962. Physical alteration of stream habitat to improve brook trout production. Trans. Am. Fish. Soc. 91(2):185-188.

Stream improvements were done on three different habitat types (pools, flat water, and riffles) within the stream. With the exception of the wire and nails used in construction, all materials used were from the immediate riparian area. Log dams, wing deflectors, and overhanging cover were constructed. In the year following reconstruction, the standing crop of fingerlings (age 0) was above average. The numbers of age 1 and older trout were doubled.

Shaw, M.A. Wasatch-Cache National Forest. In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Temple Fork Creek, Logan River drainage, has undergone stream habitat enhancement since the 1930's. In 1963, three log K-dams and three double-log wing deflectors were installed. Fish populations (brown, cutthroat, and rainbow) increased by 100%.

Shetter, D.S., O.H. Clark, and A.S. Hazzard. 1946. The effects of deflectors in a section of a Michigan trout stream. Trans. Am. Fish. Soc. 76:248-278.

Installation of 24 pool-forming deflectors raised the number of good pools from 9 to 29, increased average pool depth by 6 inches, and exposed additional gravel downstream of structures, significantly changing the average stream depth. Brook trout populations increased 120% and it was demonstrated that migration into the section was improved but was not responsible for the increase. Also, bordering sections failed to have fish populations comparable to the improved section.

Smith, B.R. 1981. Thomas Fork cooperative aquatic habitat management plan, progress report. Bureau of Land Management, Rock Springs District, Kemmerer Area, USDA, 23 pp.

Article outlines efforts to improve habitat for Utah cutthroat trout (Salmo clarki), previously believed to be extinct in its true unhybridized form. Four years after initial improvements, there has been a 25% increase in total

fisheries biomass and a 70% increase in trout biomass. This corresponds to an 83% increase in numbers of trout per mile. In addition, two new species have moved into the study area (whitefish and mountain suckers). These increases have occurred despite an increase in fishing pressure.

Stream Improvement Projects in Wyoming. In: Rocky Mountain Stream Habitat Management Workshop, Jackson Hole, Wyoming. September 7-10, 1982.

Brief descriptions of 20 stream improvement projects in Wyoming. One documented improvement was given for work done by Wyoming Game and Fish Departments on Three Channel Spring Creek, Teton County. In this project spawning riffles were rejuvenated by removing compacted cobble, adding gravel, and placing large snags as cover. Cutthroat spawning activity increased from 70 redds/year in 1970-71 to 225 redds/year by 1980.

Stream Renovation Guidelines Committee. 1983. Stream obstruction removal guidelines. American Fisheries Society and Wildlife Society.

Tarzwell, C.M. 1936. Experimental evidence on the value of trout stream improvement in Michigan. Trans. Am. Fish. Soc. 66:177-187.

Methods are developed for the improvement of trout streams and then tested and shown to be most effective in producing positive changes in overall productivity, especially in bottom pool and shallow riffle faunas.

Tarzwell, C.M. 1938. An evaluation of methods and results of stream improvements in the S.W. Trans. 3rd N. Amer. Wildlife Conf. pp. 339-367.

Compared an improved stream (Horton Creek) with an unimproved stream (Upper Tonto Creek). It was shown that even though Upper Tonto received nearly twice as many stocked fish as Horton, the total fish yield from Horton was greater each year. It also appeared that the improvements increased the natural reproduction as evidenced by the greater number of young trout in Horton Creek.

Todd, D.J. 1972. Effects of low gabion dams on primary production in high altitude streams. J. Colorado-Wyoming Acad. Sci. 7(2-3): 86.

Wydoski, R.S., and D.A. Duff. 1982. Indexed bibliography on stream habitat improvement (revised). U.S.D.A. Forest Service, Intermountain Expt. Sta., Ogden, Utah. 143 pp.

A review and discussion of the varying types of stream habitat improvement as it relates to the Intermountain West. Duff found that properly constructed instream structures in desert mountain ranges within the great basin can benefit rare native salmonid species even in high gradient streams that are subject to high fluctuations in runoff. Increases in trout populations were shown to accompany stream habitat improvement. Increases ranged from 143% in a midwest stream to 243% and 128% in two Intermountain West streams.

RIPARIAN

American Fisheries Society, Western Division. 1982. The best management practices for the management and protection of western riparian stream ecosystems. Riparian Habitat Committee.

Brazier, J.R. and G.W. Brown. 1973. Buffer strips for stream temperature control. School Forest., Oregon State University, Corvallis. Res. Pap. 15. 9 pp.

Claire, E. Oregon Department of Fish and Wildlife. In: Proceedings of Fish Habitat Improvement Workshop, Ochoco Ranger Station. September 26-27, 1978.

A six mile section of Camp Creek, Middle Fork John Day drainage, was fenced in 1976 to exclude cattle grazing from a historically heavily-grazed area. A 21-year record of steelhead spawning surveys show that in recent years there has been a redd count of 16.9 per mile outside of the area and 30.0 inside. A four year average of samples inside the area show 415 juvenile steelhead and 208 outside. Dace populations were the reverse. There were 93 inside and 663 outside. There were no juvenile dace in the protected area and few "0" age steelhead outside.

Wydoski, R.S., and D.A. Duff. 1982. Improved physical habitat in a stream enhancement project. U.S.D.A. Forest Service, Intermountain Exper. Sta., Ogden, Utah. 111 pp.

A review and discussion of the varying types of stream habitat improvements as it relates to the Intermountain West. Duff found that properly constructed instream structures in desert mountain ranges within the great basin can benefit rare native salmonid species even in high gradient streams that are subject to high fluctuations in runoff. Increases in trout populations were shown to accompany stream habitat improvement. Increases ranged from 141% in a midwest stream to 263% and 128% in two Intermountain West streams.

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American Fisheries Society, Western Division. 1981. The best management practices for the management and protection of western riparian stream ecosystems. Riparian Habitat Committee.

Brazier, J.R. and G.W. Brown. 1973. Buffer strips for stream temperature control. Forest Research. Oregon State University, Corvallis. Res. Pap. 15. 9 pp.

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Appendix II

APPENDIX II: ANALYSIS OF SUCCESS AND COST EFFECTIVENESS OF RECLAMATION PRACTICES

July, 1985

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Members of the Project Coordinating Committee reviewed the draft report and their comments are included in this document.

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INTRODUCTION

THE COOPERATIVE WILDLIFE PROGRAM

The Overthrust Industrial Association (OIA) is currently carrying out its Cooperative Wildlife Program, which consists of three elements. These are law enforcement assistance, an environmental awaremenss training program and a wildlife management study. The wildlife management study area encompasses areas within portions of the Overthrust Belt located in Uinta and Lincoln Counties in Wyoming, Rich and Summit Counties in Utah and Bear Lake County in Idaho. The study consists of three phases.

Phase I has been completed and consisted of a literature search and review, and the design of Phase II. Its objective was to assess the state of current knowledge concerning wildlife resources in the Overthrust Belt in Wyoming, Idaho and Utah, and to determine the sufficiency of existing information and analytical methods for understanding, predicting and mitigating the adverse effects of development on wildlife resources. Phase I was conducted by Larry Seeman Associates, Inc. in Berkeley, California and the University of Wyoming in Laramie, Wyoming. Their findings, recommendations for further research, and annotated bibliography are presented elsewhere (Overthrust Industrial Association 1984).

Phase II will consist of collection and analyses of necessary field data that will be developed in four projects: land reclamation, habitat mapping, sedimentation and mitigation. These studies will develop a set of analytical procedures that can be used to mitigate adverse effects of industrial development on wildlife. The four projects of Phase II were initiated in the spring of 1984. This report documents the findings from Task I of the land reclamation project of Phase II.

Phase III will include the development of government and management recommendations concerning analytical procedures and identification of potential environmentally sensitive areas, mitigation alternatives and distribution of the final work products. This phase of the study has yet to be initiated.

LAND RECLAMATION OBJECTIVES AND TASKS

Objectives associated with the land reclamation project of Phase II include:

- To determine from agency and accessible company records and personal interviews the success and costs of reclamation techniques tested and used both in the study area and adjacent areas with similar climatic and physical conditions.

- To determine whether various types of energy development projects had stated reclamation objectives and compare the results with past reclamation activities to determine major problems and effective practices.

- To evaluate techniques or combinations of techniques in terms of their effectiveness in meeting stated reclamation objectives.

- To recommend for testing those cost-effective reclamation techniques or other areas where data is needed to improve reclamation and meet stated objectives.

- To develop a reclamation manual for use in the field.

- To conduct meetings and a workshop with the Project Coordinating Committee of the Cooperative Wildlife Program.

Four tasks and associated subtasks were identified to achieve these objectives. The task headings are: Task I - Literature Review and Personal Interviews, Task II - Field Assessments and Cost Effectiveness, Task III - Reclamation Manual, and Task IV - Public Workshop and Meetings. This report documents the findings of Task II. Four subtasks were identified for this task:

- Select sites of field studies that represent a diversity of habitats and reclamation techniques utilized in site rehabilitation.

- Visit sites and gather data on success of reclamation techniques, problems associated with different techniques or weed species invasion and the occurrence of erosion.

- Summarize data and run statistical analyses to identify common problems associated with development in the overthrust area in order to provide for adequate mitigation.

- Findings of the second task are to be documented in a written report and presented to the PCC in the second meeting.

METHODS

STUDY AREA

The study area for the field investigation (Task II) consisted of the five counties surrounding the major developed oil and gas fields of the Overthrust Belt. The five counties are Bear Lake (Idaho), Rich and Summit (Utah) and Uinta and Lincoln (Wyoming). The study sites are shown in Figure 1. The majority of the sites were located in Wyoming since that was the area with the greatest development. Approximately 13 percent of the sites were located in Utah and 5 percent were located in Idaho. There was a total of 101 sites sampled.

The sites were selected subjectively with the basic criteria of sampling as much variability as was possible both from an environmental perspective and from a time perspective. Selection criteria included such things as:

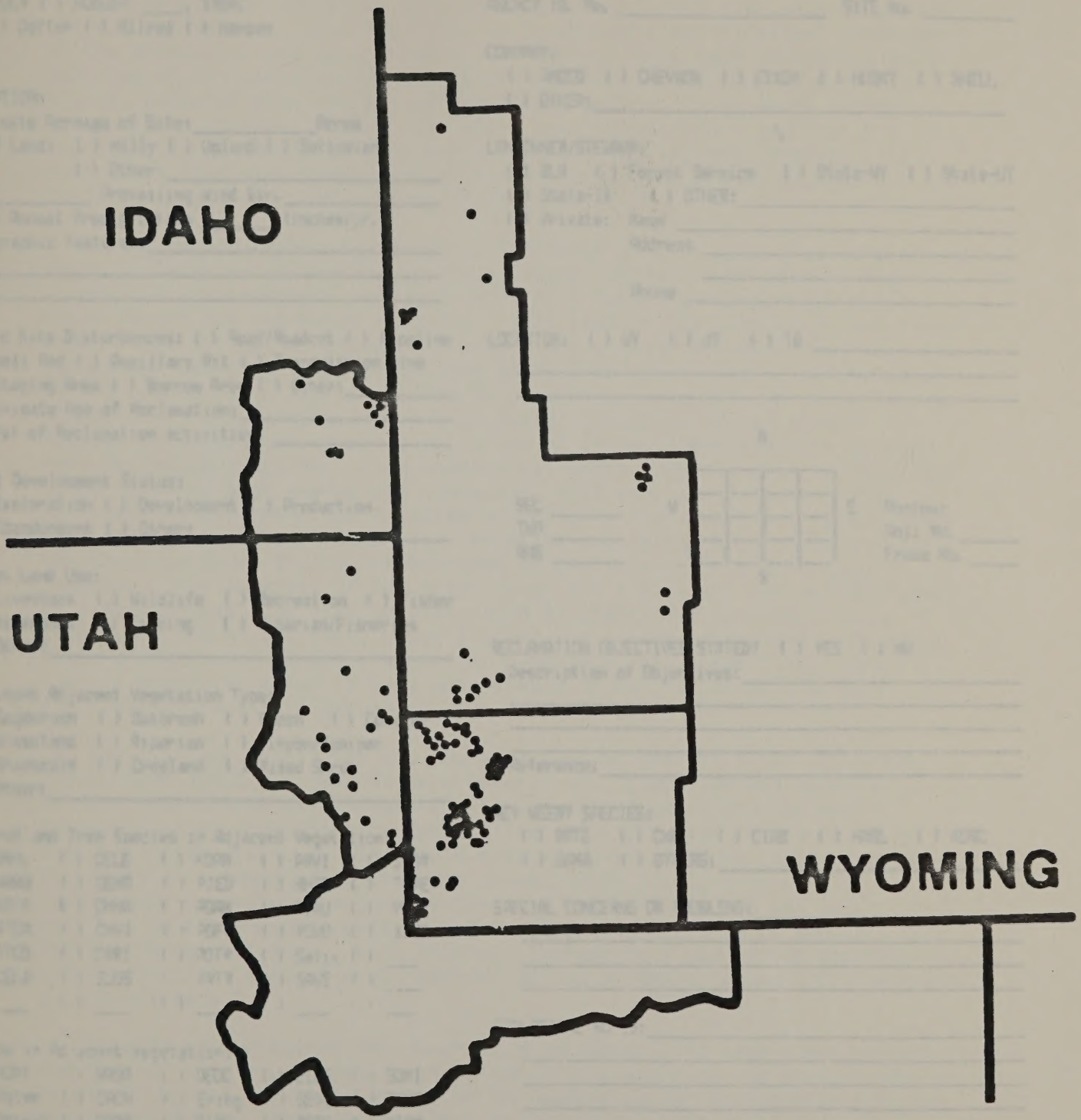
- Sites representative of innovative reclamation techniques.
- Sites typical of commonly occurring reclamation problems.
- Sites reseeded prior to 1980 when shrub and forb species were commonly used in seed mixes.
- Sites reseeded after 1980 when predominantly grass species were included in the seed mixes.
- Sites representative of various types of disturbances such as pipelines, roads, drill pads, etc.
- Sites located in different vegetation types.
- Sites located in different precipitation zones.
- Sites characterized as having exceptional colonization of nonseeded forb and shrub species.

Most of the sites were located in the major development centers of oil and gas activities such as the Whitney Canyon/Carter Creek area, Ryckman Creek area, Painter Reservoir area and Anschutz Ranch area. These sites had a greater number of various revegetation techniques applied including topsoiling and no topsoiling, hydroseeding, netting (jute, excelsior, etc.), mulching, and soil erosion techniques including terracing, contour furrowing, and contour ripping. The older sites were generally associated with abandoned sites and exploratory wells which were scattered throughout the study area.

INFORMATION GATHERED

At each site a description sheet was filled out which described the important site characteristics. An example of the data format is shown in

Figure 1. Location of the study sites.



IDAHO
UTAH
WYOMING

Figure 2. Example of Data Sheet Format for Documenting Site Information.

COOPERATIVE WILDLIFE PROGRAM PHASE II
RECLAMATION STUDY

PAGE 1 OF 3

DATE: ( ) JULY ( ) AUGUST ____, 1984.
DATA BY: ( ) Ostler ( ) Allred ( ) Hansen

SITE DESCRIPTION:
Approximate Acreage of Site:_____Acres
Kind of Land: ( ) Hilly ( ) Upland ( ) Bottomland
( ) Other _____
Elev._____ Prevailing Wind Dir._____
Average Annual Precipitation _____ (inches/yr.)
Physiographic features:_____

Historic Site Disturbances: ( ) Road/Roadcut ( ) Pipeline
( ) Well Pad ( ) Auxillary Pit ( ) Transmission line
( ) Staging Area ( ) Borrow Area ( ) Other:_____
Approximate Age of Reclamation:_____
Year(s) of Reclamation activities: _____

Current Development Status:
( ) Exploration ( ) Development ( ) Production
( ) Abandonment ( ) Other:_____

Previous Land Use:
( ) Livestock ( ) Wildlife ( ) Recreation ( ) Timber
( ) Watershed ( ) Farming ( ) Riparian/Fisheries
( ) Other:_____

Predominant Adjacent Vegetation Type:
( ) Sagebrush ( ) Oakbrush ( ) Aspen ( ) Conifer
( ) Grassland ( ) Riparian ( ) Pinyon/Juniper
( ) Shadscale ( ) Cropland ( ) Mixed Shrub
( ) Other:_____

Key Shrub and Tree Species in Adjacent Vegetation:

( ) ARAR	( ) CELE	( ) KOPA	( ) PRVI	( ) SYOR
( ) ARNO	( ) CEMO	( ) PIED	( ) RHTR	( ) TAPE
( ) ARTR	( ) CHNA	( ) POPA	( ) RIAU	( ) YUEL
( ) ATDA	( ) CHVI	( ) POFR	( ) POMO	( ) IASA
( ) ATCO	( ) CRRI	( ) POTR	( ) Salix	( ) ___
( ) CELA	( ) JUOS	( ) PRTR	( ) SAVE	( ) ___
( ) ___	( ) ___	( ) ___	( ) ___	( ) ___

Key Forbs in Adjacent Vegetation:

( ) ACHI	( ) BASA	( ) DEDC	( ) LILE	( ) SOMI
( ) Aster	( ) CRCH	( ) Eriog	( ) OEPU	( ) TAOF
( ) Astrag	( ) COPA	( ) SIAS	( ) PEPA	( ) VIAM
( ) ____	( ) ____	( ) ____	( ) ____	( ) ____

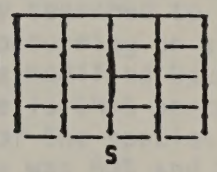
AGENCY ID. No. _____ SITE No. _____

COMPANY:
( ) AMOCO ( ) CHEVRON ( ) EXXON ( ) HUSKY ( ) SHELL
( ) OTHER:_____

LANDOWNER/STEWARD:
( ) BLM ( ) Forest Service ( ) State-WY ( ) State-UT
( ) State-ID ( ) OTHER:_____
( ) Private: Name _____
Address _____
_____
Phone _____

LOCATION: ( ) WY ( ) UT ( ) ID _____

SEC _____
TWP _____
RNG _____



Photos:
Roll No._____
Frame No._____

RECLAMATION OBJECTIVES STATED? ( ) YES ( ) NO
Description of Objectives:_____

Reference:_____

KEY WEEDY SPECIES:
( ) BRTE ( ) CHAL ( ) CIAR ( ) HABL ( ) KOSC
( ) SAKA ( ) OTHERS:_____

SPECIAL CONCERNS OR PROBLEMS:_____

ECOLOGICAL NOTES:_____

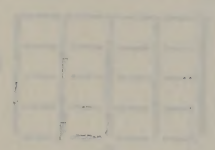


Figure 2. Areas within a site (referred to as subsites) that appeared to be characteristic of that site were sampled for both erosion condition and revegetation success. Examples of these forms are shown in Figures 3-4.

The degree and extent of erosion occurring on each site were determined through the use of a modified "Erosion Condition Classification" developed by the Bureau of Land Management (Clark 1980). Only four categories were selected of the seven proposed by Clark (1980). Those four were surface litter, pedestalling, rills (< 9" deep) and gullies (> 9" deep). Each category was assigned a numerical score ranging between 1 and 5 with 1 representing no visual effects and 5 representing extreme effects. The four categories were summed for each subsite to generate an erosion condition class for that subsite (Table 1).

Other physiographic factors that influence erosion were also sampled. These included slope steepness, slope length, surface soil texture and aspect. Slope steepness was measured with a hand held clinometer while slope length was estimated visually. Soil texture was sampled in the field using field estimation procedures. Soil was classified into broad textural groups such as clay loam, sandy clay loam, loam, etc. Aspect was measured with a compass and later converted to reflect solar radiation and effective moisture using a formula reported by Beers, Dress and Wensel (1966). Vegetation cover, perennial cover, cover of litter, rock and bare ground were estimated visually. Each subsite was thoroughly searched to identify those species, both seeded and nonseeded, that were occurring on site. Each species was rated for relative abundance using a modified Daubenmire classification (Daubemire, 1954). Relative abundance is that percentage of the absolute cover that is contributed by the cover of the species of interest. For example, if the total cover for a site was 50% and the cover of a species was 10%, that species would be classified as common since it represents 20% of the total cover (10/50). The categories were: abundant (over 25%), common (5-25%), uncommon (1-5%) and rare (under 1%). The species were also noted if they were seeded or not, although this was sometimes difficult to determine.

The adjacent vegetation was characterized by habitat type. Dominant shrub, forb and grass species were identified. Elevation was measured using a WEATHERtronics altimeter. Average annual precipitation was estimated using precipitation data published by the USDA (1941) on sites near recording stations. In remote areas precipitation was estimated based on vegetation communities. The age of each site (i.e., time since disturbance or reclamation) was determined in the field and was later verified to the extent possible by BLM and private records or people familiar with that site. Each site was located on a map to the nearest quarter section, ownership was determined and a general photo taken to show site conditions.

Records were obtained for numerous sites specifying seed mixes, rates and time of seeding. However, these specifications were not always adhered to either by the drilling company or the subcontractor responsible for the actual reseeding. Notes on reclamation techniques that were used and problems that occurred were also recorded.

Figure 3. Type of erosion data collected.

Site No. _____ Subsite No. _____ Description _____

Surface Litter	Pedestalling	Rills <9"	Rills >9"
Accumulating in Place	No visual evidence	No visual evidence	No visual evidence
Slight Movement	Slight pedestalling	Rills in evidence at intervals >10'	Rills in evidence at intervals >10'
Moderate Movement	Small rock and plant pedestalling	Rills at 10' intervals	Rills at 10' intervals
Extreme Movement	Pedestalling evident plant roots exposed	Rills at 5-10' intervals	Rills at 5-10' intervals
Very Little Remaining Litter	Most plant and rocks pedestalled and roots exposed	Rills at <5' intervals	Rills at <5' intervals

Aspect ____ Slope ____ Slope Length ____ Surface Soil Texture _____

Notes on observed erosion control techniques and their effectiveness:

Figure 4. Type of revegetation data collected.

Site No. _____ Subsite No. _____

Total Plant Cover (%) _____

Perennial Plant Cover (%) _____

Litter Cover (%) _____

Rock Cover (%) _____

Bare Ground (%) _____

Perennial Species

Species-Code	Seeded	Abundant < 25%	Common 5-20%	Uncommon < 5%

Table 1. Erosion condition classes-rating based on adjusted rate as determined by the BLM.

Numerical Rating	Erosion Condition Class
0 - 4.0	stable
4.1 - 8.0	slight
8.1 - 12.0	moderate
12.0 - 16.0	critical
16.1 - 20.0	severe

ANALYSIS OF DATA

All data that were gathered in the field and in subsequent communications were reviewed for errors or deficiencies and transferred onto computer cards and later to magnetic disk for analysis and storage. Data were analyzed using SPSS programs developed by Nie et al. (1978). Due to the large data set (176 subsites) analyses was done on a Univac 1100 mainframe computer. Analyses consisted of descriptive statistics, regression and correlation analysis, multiple regression analysis, analysis of variance, mean separation tests and t-tests. All the raw data that was used for computer analysis is included in Appendix 4.

RESULTS AND DISCUSSION

GENERAL OBSERVATIONS

Types of Disturbance

Of the total number of subsites sampled, over 80% occurred in Wyoming, while 13% occurred in Utah and 5% occurred in Idaho. The majority of the disturbances sampled occurred on federally owned land. Approximately 55% of the sites were on BLM adminstered land and 10% on USFS administered land. Privately owned land represented 34% of the sites sampled and the State of Wyoming owned 2% of the sites sampled (Table 2). This ratio of land ownership represents a good characterization of the actual overall surface ownership except that percentage of privately owned surface is somewhat higher. The reason for the fewer samples on private land was that access to private land was often difficult to obtain and very time consuming.

Disturbances were of three basics types: roads, drill pads (or production facilities) and pipelines. The disturbances associated with drill pads represented 77% of the sites sampled. Those associated with roads represented 9% and those associated with pipelines represented 14%.

Vegetation Types

The disturbances occurred in seven different vegetation types (Table 3). The sagebrush type was the most commonly disturbed vegetation type with nearly 53% of the samples being taken in this type. The next most common type was the pinyon-juniper vegetation type which represented 15% of the sites sampled. These were followed by mixed shrub and grasslands both at 11%, conifer at 5%, aspen at 3% and shadscale at 1%. These percentages appear to represent the overall distribution of disturbances in the Overthrust Belt area. Most disturbances were in upland areas which are more representative of summer range for big game rather than winter range.

The most common woody species that occurred in the adjacent communities are shown in Table 4. The most common woody species were big sagebrush which occurred in 76% of the sites and Douglas rabbitbrush which occurred on 75% of the sites. A distant third was snowberry with 41%, followed by serviceberry with 31% and black sagebrush with 30%. (See Appendix 1 for scientific names and codes for species).

The most commonly occurring forbs are reported in Table 5. The most commonly occurring forb was aster which occurred on 44% of the sites. Wild buckwheats were the second most common species occurring in 41% of the adjacent native vegetation. These were followed by lupine and balsamroot which occurred in 19% and 16% of the sites, respectively.

The most commonly occurring grasses were western wheatgrass occurring in 53% of the adjacent communities, and bluebunch wheatgrass occurring in 46% of the adjacent communities (Table 6). The bluegrasses were the next most common with a 44% occurrence. The needlegrasses were much less common occuring on only 17% of the sites followed by Indian ricegrass occurring on 16% of the sites.

Table 2. Land ownership of subsites in each of the three states in the study area.

OWNER		STATE Idaho	Utah	Wyoming	ROW TOTAL
BLM	COUNT	0	14	82	96
	ROW PCT	0.0	14.6	85.4	100.0
	COL PCT	0.0	63.6	56.6	
	TOT PCT	0.0	8.0	46.6	54.5
FOREST SERVICE		9	0	9	18
		50.0	0.0	50.0	100.0
		100.0	0.0	6.2	
		5.1	0.0	5.1	10.2
PRIVATE		0	8	51	59
		0.0	13.6	86.4	100.0
		0.0	36.4	35.2	
		0.0	4.5	29.0	33.5
STATE		0	0	3	3
		0.0	0.0	100.0	100.0
		0.0	0.0	2.1	
		0.0	0.0	1.7	
COLUMN TOTAL		9	22	145	176
		100.0	100.0	100.0	100.0
		5.1	12.5	82.4	100.0

Table 3. Types of disturbances in each vegetation type.

Disturbance		Vegetation Type: Aspen	Conifer	Grassland	Shadscale	Mixed Shrub	Pinyon-Juniper	Sagebrush	ROW TOTAL
PAD	COUNT	5	8	11	2	16	20	74	136
	ROW PCT	3.7	5.9	8.1	1.5	11.8	14.7	54.4	100.0
	COL PCT	83.3	88.9	55.0	100.0	80.0	76.9	79.6	
	TOT PCT	2.8	4.5	6.3	1.1	9.1	11.4	42.0	77.5
ROAD		0	1	1	0	2	1	11	16
		.0	6.3	6.3	.0	12.5	6.3	68.8	100.0
		.0	11.1	5.0	.0	10.0	3.8	11.8	
		.0	.6	.6	.0	1.1	.6	6.3	9.1
PIPELINE		1	0	8	0	2	5	8	24
		4.2	.0	33.3	.0	8.3	20.8	33.3	100.0
		16.7	.0	40.0	.0	10.0	19.2	8.6	
		.6	.0	4.5	.01.1	2.8	4.5		13.6
COLUMN TOTAL		6	9	20	2	20	26	93	176
		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
		3.4	5.1	11.4	1.1	11.4	14.8	52.8	100.0

Table 4. Common woody species in the adjacent undisturbed communities.

Common Name	Scientific Name	Occurrence (%)
Big sagebrush	Artemisia tridentata	76
Douglas rabbitbrush	Chrysothamnus viscidiflorus	75
Snowberry	Symphoricarpos oreophilus	41
Serviceberry	Amelanchier alnifolia	31
Black sagebrush	Artemisia nova	30
Utah juniper	Juniperus osteosperma	22
Rubber rabbitbrush	Chrysothamnus nauseosus	20
Winterfat	Ceratoides lanata	16
Aspen	Populus tremuloides	11
Bitterbrush	Purshia tridentata	10
Fringed sagebrush	Artemisia frigida	8
Oregon grape	Mahonia repens	7

All others occurred on less than 5% of the sites.

Table 5. Common forbs occurring in the adjacent undisturbed communities.

Common Name	Scientific Name	Occurrence (%)
Aster	*Aster* spp. (*A. occidentalis* dominant)	44
Wild buckwheat	*Eriogonum* spp. (*E. umbellatum* dominant)	42
Yarrow	*Achillea millefolium*	41
Lupine	*Lupinus candatus*	19
Balsamroot	*Balsamorhiza sagittata*	16
Lewis flax	*Linum lewisii*	6
Richardson geranium	*Geranium richardsonii*	5
Goldenweed	*Haplopappus acaulis*	5

All other forbs occurred on less than 5% of the sites.

Table 6. Common grasses in the adjacent undisturbed communities.

Common Name	Scientific Name	Occurence (%)
western wheatgrass	Agropyron smithii	53
bluebunch wheatgrass	A. spicatum	46
bluegrass	Poa sp.	34
	(P. fendleriana, P. secunda dominant)	17
needlegrass	Stipa columbiana	17
Indian ricegrass	Oryzopsis hymenoides	16
Thickspike wheatgrass	A. dasystachyum	12
Kentucky bluegrass	Poa pratensis	10
Mountain brome	Bromus marginatus	7
Prairie Junegrass	Koeleria cristata	6
Great Basin wildrye	Elymus cinereus	6

Table 6. Common grasses in the adjacent wheatbelt communities.

Common Name	Scientific Name	Occurrence (%)
western wheatgrass	*Agropyron smithii*	53
bluebunch wheatgrass	*A. spicatum*	46
bluegrass	*Poa* sp.	34
	(*P. pseudoalpina*, *P. secunda*	17
	Scribn.)	17
needlegrass	*Stipa columbiana*	16
Indian ricegrass	*Oryzopsis hymenoides*	12
Thickspike wheatgrass	*A. dasystachyum*	10
Kentucky bluegrass	*Poa pratensis*	7
Mountain brome	*Bromus marginatus*	6
Prairie Junegrass	*Koeleria cristata*	6
Great Basin wildrye	*Elymus cinereus*	

Reclamation Problems

During the field assessment, numerous problems were observed with reclamation techniques that were either improperly selected or implemented. It was not the intent of this study to quantify the occurrence of these problems but they were noted on the site description forms so that they could be addressed in the reclamation manual. These problems were later summarized by category. Nine categories were recognized including: water control techniques, vegetation removal, snow management, site preparation, topsoiling, seeding, mulching, weeds and spills.

By far the most common problems were with water control techniques. Problems observed in this category include:

- Drainage from the pad was allowed to run over the edge of the slope causing severe gullying.
- Improper techniques were used, such as using terraces when contour furrows would have been sufficient.
- Improper construction of water bars, such as poor drainage, too wide, steep backslope on terraces, too shallow, draining too steeply, and not placed on the contour (Figure 5-6).
- Streams were improperly rechanneled.
- There was a lack of interceptor ditches to avoid runoff from slopes above the disturbances.

Water control problems, if not corrected, can result in severe erosion and can jeopardize the stability of a site. Proper erosion control during planning and construction can minimized expensive maintenance costs later on which may require remobilization of heavy equipment.

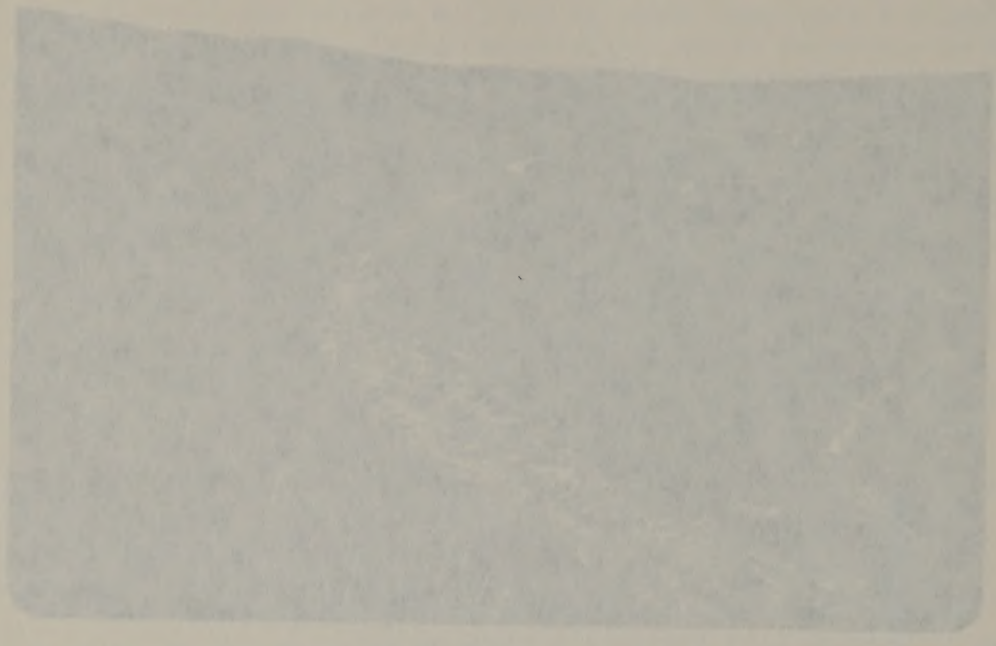
Another common problem that was observed was the excessive removal of vegetation, principally by cattle. The problem of overgrazing was evident on numerous sites. Overgrazing is particularly damaging during the initial season of plant establishment when plant carbohydrate reserves are low. Cattle often preferred grazing the reclaimed areas to adjacent natural vegetation because of the succulent vegetation, domination of grass species and more gentle slopes.

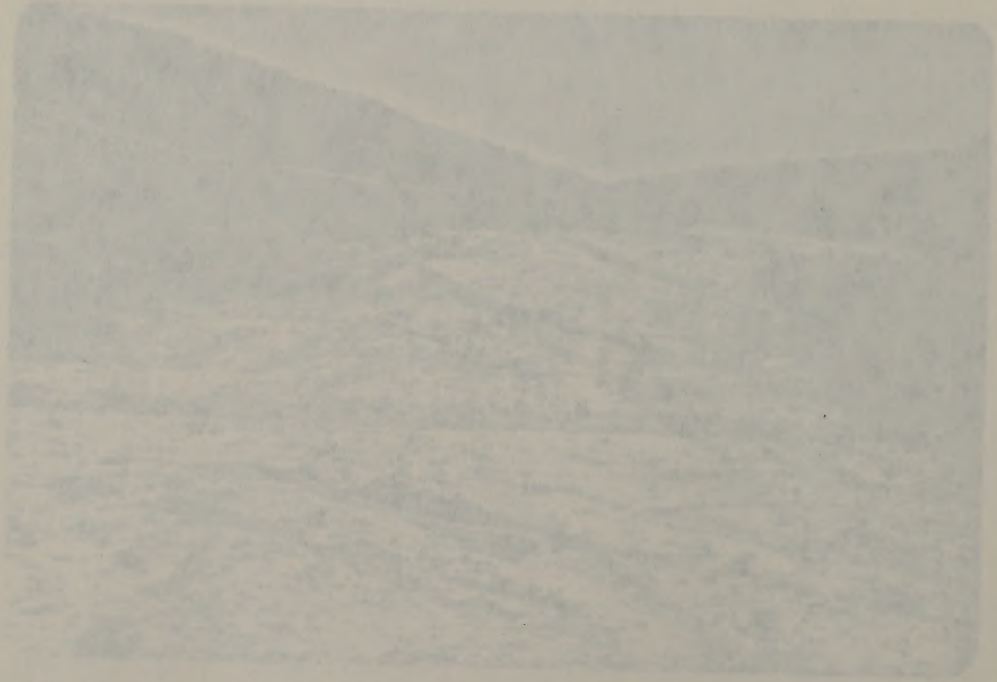
A rather localized problem was snow management. Improper placement of sites in areas subject to snow accumulation aided in causing slope failure and eventual slumping. Large drifts or piling of snow during snow removal operations were observed to cause severe erosional problems. These large piles often serve to catch more snow and the snow spills over containment berms. The resulting snow melt can erode reclaimed slopes.

Proper site preparation prior to seeding was observed to be a problem at several locations. Improper site preparation included inadequate ripping of compacted areas, working of the soil when it was too wet, and failure to rip on the contour. Improper site preparation leads to poor

Figure 5. Example of terraces that have excessively steep backslopes.

Figure 6. Example of water bars not being placed on the contour.





seedling establishment and reduces plant growth.

The lack of topsoil was another common problem observed. Areas that were not topsoiled generally had far poorer revegetation success than comparable areas on the same site that were topsoiled.

The lack of proper seeding techniques was evident of several sites. Problems relating to improper seeding included improper timing of seeding, improper seed mixtures, excessive length of time prior to seeding, drill seeding up and down slopes etc. Seed mixes that were specified by either the land owner or manager were not always adhered to and this hindered our assessment of species performance.

The improper use of mulch or no use of mulch when it certainly would have been a benefit to reduce soil erosion was a problem on several sites. Netting was also used improperly, such as on gentle slopes that did not require netting or as an after thought years after erosional rills and gullies had already occurred (Figures 7-8). In this "bandaid" approach, netting or mulch was used to stop erosion without correcting the problem of improper water control. There were areas where the mulch was actually causing more damage than good due to competition from weeds that became established from seeds in the mulch. In some cases, burlap netting impaired young plants from growing.

Weeds were a problem on several sites. There were several noxious weeds that were observed on the sites sampled. These should be controlled so they do not spread onto other disturbed sites in the area. With the large number of disturbances in some developing fields this could become a serious problem.

The final problem was documented on only site but deserves mention. This was the lack of revegetation success due to apparent hydrocarbon contamination of the soil Although this was an isolated event, it could have a significant impact if the material was toxic to plants or animals. It points out an important consideration for almost all drill sites which is the proper disposal of drilling fluids, muds, and other chemicals that are used in the development process and that are generally disposed of on-site.

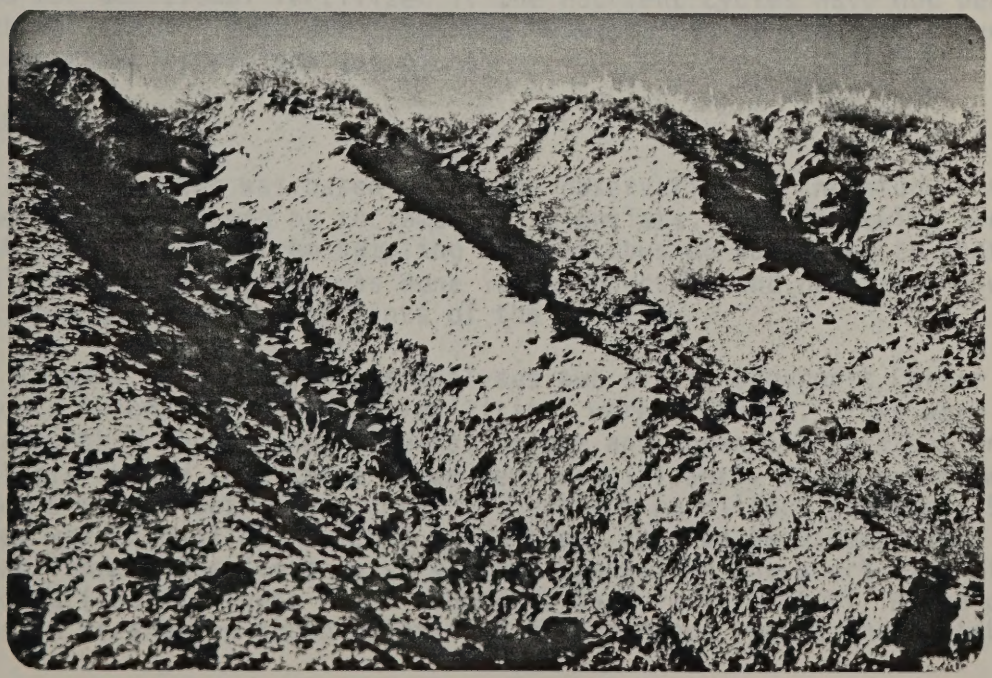
These problems do not necessarily indicate that the quality of revegetation currently taking place is below standard. Significant improvements have been made over the past few years and conscientious efforts are generally more prevalent, although localized problems continue to occur. It is important to recognize the problems that have occurred in order to minimize them in future efforts.

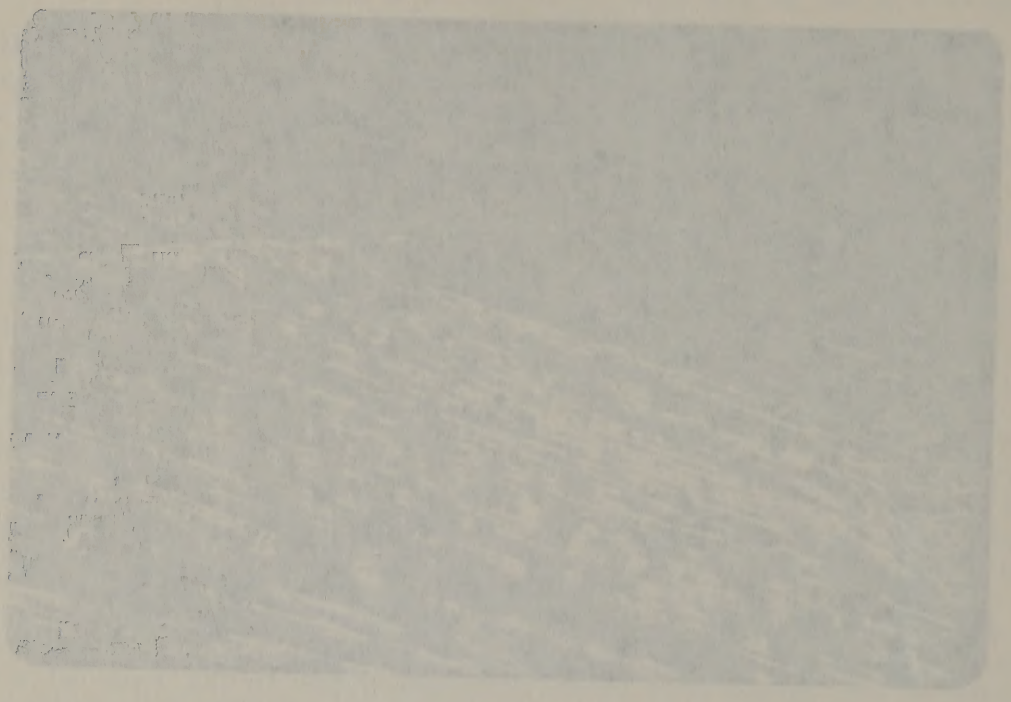
Goals, Compliance and Cost Effectiveness

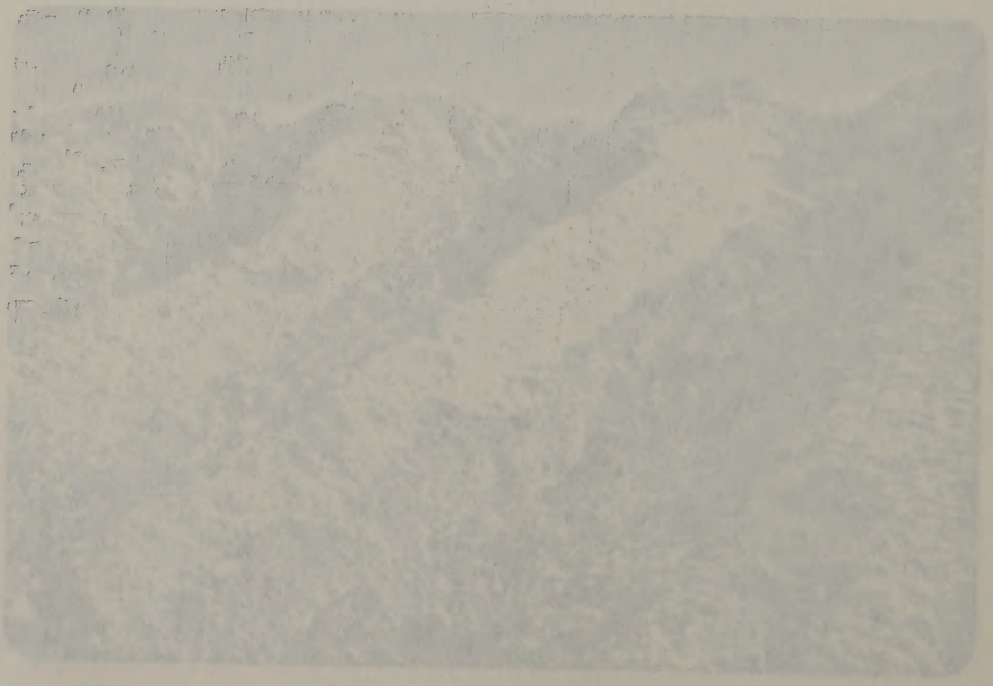
Other problems existed that were not associated with implementation techniques but involved lack of preplanning and follow-up by both the oil and gas developer and the land owner or manager. Perhaps the most important problem in this category was the lack of specific reclamation objectives. It was commonly stated on permit applications that the site would be "revegetated". This is much too subjective a term to ensure

Figure 7. Application of jute netting after erosional patterns had already started. The jute was relatively ineffective.

Figure 8. Example of a "bandaid" approach to stop erosion without correcting the driving force, water draining off the pad above.







adequate site protection and reclamation. It is to the benefit of both the developer and the land owner to agree on specific goals regarding the success of reclamation. Without a specific goal the developer may be required to do more than is reasonable, such as hauling in 2 feet of topsoil onto a site when only 6 inches existed prior to disturbance.

Compliance evaluations currently consist of a rather subjectivve evaluation of the reclamation effort and an interpretation of how the site will respond during the following ten years or until the disturbance returns to a somewhat natural or self-sustaining condition. Once a site is deemed acceptable by the land manager any further responsibility is removed from the developer. It appears that making this decision of acceptance is important and should be based on something more than a subjective analysis which is sometimes done without ever visiting the site.

Without an established reclamation goal a cost-effective evaluation is not necessary since the least-cost option (do nothing) would always be the most cost-effective alternative. The Bureau of Land Management for the Kemmerer Resource Area stated that their main goal is erosion control, yet there is no effective monitoring to evaluate whether that goal is ever achieved. To effectively do a cost-effectiveness evaluation there needs to be follow-up monitoring of a quantitative nature.

Maintenance

A major problem that was observed was the lack of maintenance or follow-up on reclaimed sites. It appeared that once a site was reseeded that it was seldom if ever visited again, not even to evaluate the success of the seeding. It was obvious that problems, particularly regarding erosion control, could be alleviated with a maintenance program. Terraces and water bars require maintenance if a site experiences much erosion. If they are not maintained they often cause more severe problems than if they had never been installed (see Figure 10). On some sites there may be a need for additional fertilizer if the nutrient cycles have not become reestablished. These are needs that appeared to be completely overlooked in the existing reclamation plans.

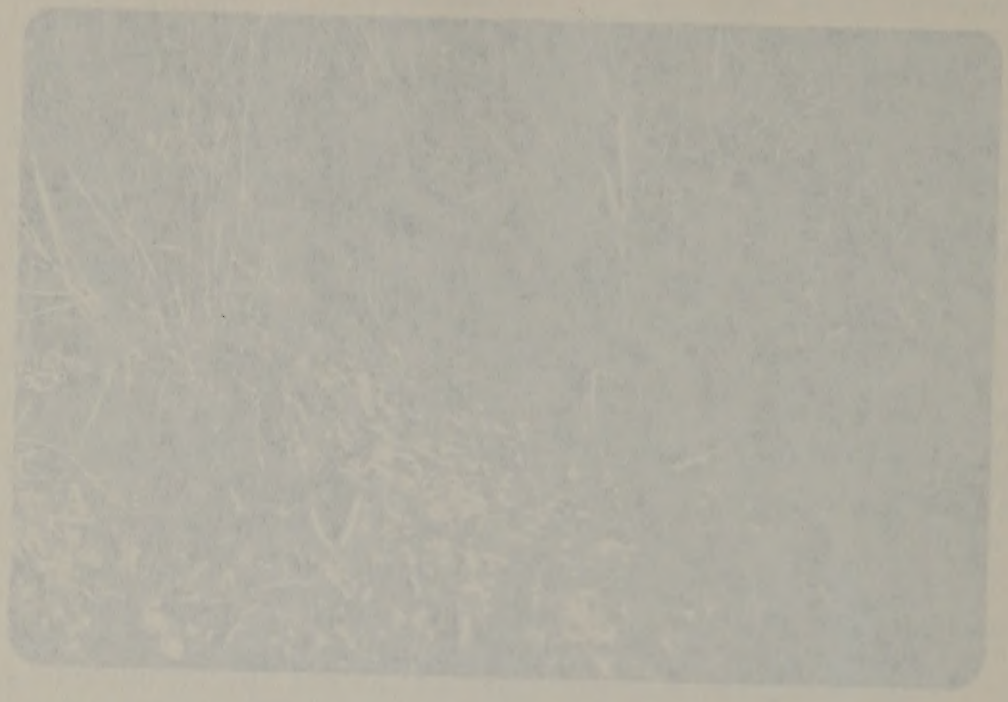
SPECIFIC ANALYSES

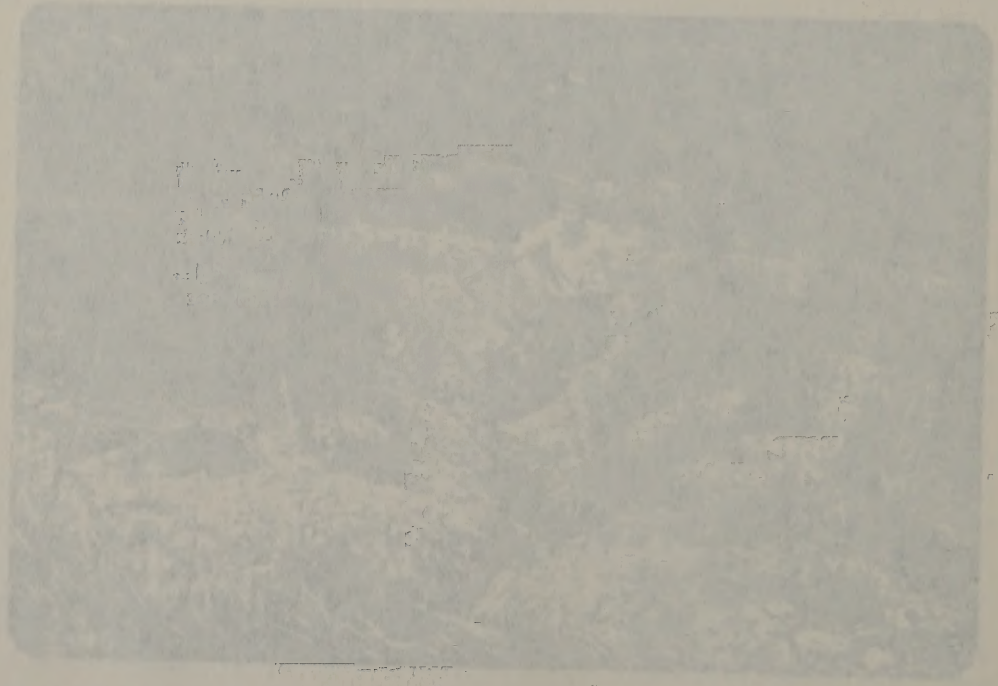
The preceding was based on visual observation of the study sites and conditions as viewed by reclamation scientists. The following are data that were gathered from sampling and can thus be subjected to statistical analysis. The sampling was done in as objective and nonbiased a way as possible given the constraints of the program.

In many of the following analyses two sites, Chevron's Carter Creek and Amoco's Anschutz Production facilities, were excluded. They were omitted because they represented somewhat unique and intensive reclamation. Analysis showed that these sites were significantly different from the other sites in both plant cover and erosion conditions (Appendix 5). Both sites were topsoiled, mulched and netted, and had excellent plant establishment despite some very steep slopes and the short time since seeding (1983). These sites tended to mask relationships in the data. Thus to strengthen those relationships and hence reduce the variability in

Figure 9. Example of pedestalling of plants due to severe erosion.

Figure 10. Example of gullies formed by improper drainage of terraces.





the data set, these sites were deleted from some analyses. It is not uncommon in statistical analysis to delete outlying data points when their response is attributed to different or unusual conditions (Neter and Wasserman, 1974).

Erosion Evaluation

The results of the analysis of the erosion condition classification show that erosion was a problem for many of the sites sampled. The average of the 176 subsites for the four erosional categories is shown in Table 7. Surface litter had an average value of 1.8 with 1 representing no litter movement and 2 representing slight movement. Pedastalling had a value of 1.9 with 1 presenting no visual evidence and 2 representing slight pedastalling (Figure 9). Rills (less than 9" deep) had the largest value with a mean of 2.4, and 2 representing rills in evidence at greater than 10' intervals, and 3 representing rills at 10' intervals. Gullies (deeper than 9") had the lowest value of 1.7 with 1 representing no visual evidence and 2 representing gullies in evidence at intervals greater than 10' (Figure 10).

A stepwise multiple regression was used to determine the factors which most influence the erosional condition classification. The values for each erosion classification were summed and utilized as the dependent variable. The principle factor identified was slope (Table 8). Slope accounted for 48% of the variability in the erosion condition classifications and was the most important factor (Figure 11). The other factors in the multiple regression equation were rock cover, total vegetation cover and silts in the soil (all negatively correlated relationships). A negatively correlated relationship means that when these factors increase the evidence of erosion decreases. With the addition of rock cover, total vegetation cover and percent silts into the model, the amount of variability that was accounted for by these four factors increased to 57% ($r^2 = .57$).

Slope obviously has a major impact on erosion, particularly if the soil is exposed with no vegetative or mulch cover. In order to breakdown the effect of slope on erosion, slope was divided into 6 categories: 1) 0-10%, 2) 11-20%, 3) 21-30% 4) 31-40%, 5) 41-50%, and 6) > 50%. The erosion condition classification values were lumped into 5 descriptive categories similar to that proposed by Clark (1980) and shown in Table 1. The maximum erosion condition classification value possible for a site was 20.

An analysis of variance indicated that there was a significant difference in the erosion condition classification value for the different levels of slope classification ($\alpha < .01$). Average erosion on slopes ranging from 0-10% and 11-20% was rated as slight while steeper slopes were rated as moderate. Table 9 displays the number of occurrences of each erosion class for each slope class. Ninety percent of the slopes ranging from 0-10% had erosion rated as stable or slight while erosion on 68% of the slopes ranging from 11-20% was rated as stable or slight. Seventy percent of the slopes ranging from 21-30% had erosion classified as moderate to critical while slopes ranging from 31-40% had 72% of their sites rated as moderate to severe. Slopes ranging from 41-50% had 43% of their sites classified as critical to severe. Slopes steeper than 40% comprised only 9% of the sites. Slopes greater than 50% (> 2 horizontal:1 vertical)

Erosion Evaluation

Table 7. Mean and standard deviation for all parameters sampled.

Variable	Variable Code	Cases	Mean	STD Dev
Elevation	Elev (m)	176	2295.1	325.2
Precipitation	PPT (cm)	176	36.1	6.6
Age	AGE (years)	176	3.5	3.6
Litter Movement	SSF1	176	1.8	1.0
Pedastalling	SSF2	176	1.9	1.1
Rills	SSF3	176	2.4	1.4
Gullies	SSF4	176	1.7	.8
Slope	SLOPE (%)	176	21.1	17.7
Slope length	SLPLNGTH (m)	176	38.6	67.5
Clay	CLAY (%)	176	30.0	14.7
Silt	SILT (%)	176	32.8	9.5
Sand	SAND (%)	176	37.2	15.3
Total Cover	TOTCOVER (%)	176	25.9	16.6
Perennial Species Cover	PERCOVER (%)	176	21.9	17.1
Litter Cover	LITTER (%)	176	10.2	13.8
Rock Cover	ROCK (%)	176	10.6	16.4
Bare ground	BARE (%)	176	53.3	24.3
Adjusted Aspect	ADJASP (1-180)	176	87.5	45.3
Latitude	HGRID	176	460.1	4.6
Erosion Condition Class	TOTSSF	176	7.8	3.9
Shrub Cover	SHRUB (%)	176	1.3	5.8
Forb Cover	FORB (%)	176	0.6	2.5
Nonseeded Cover Species	INVADER	176	1.9	7.4

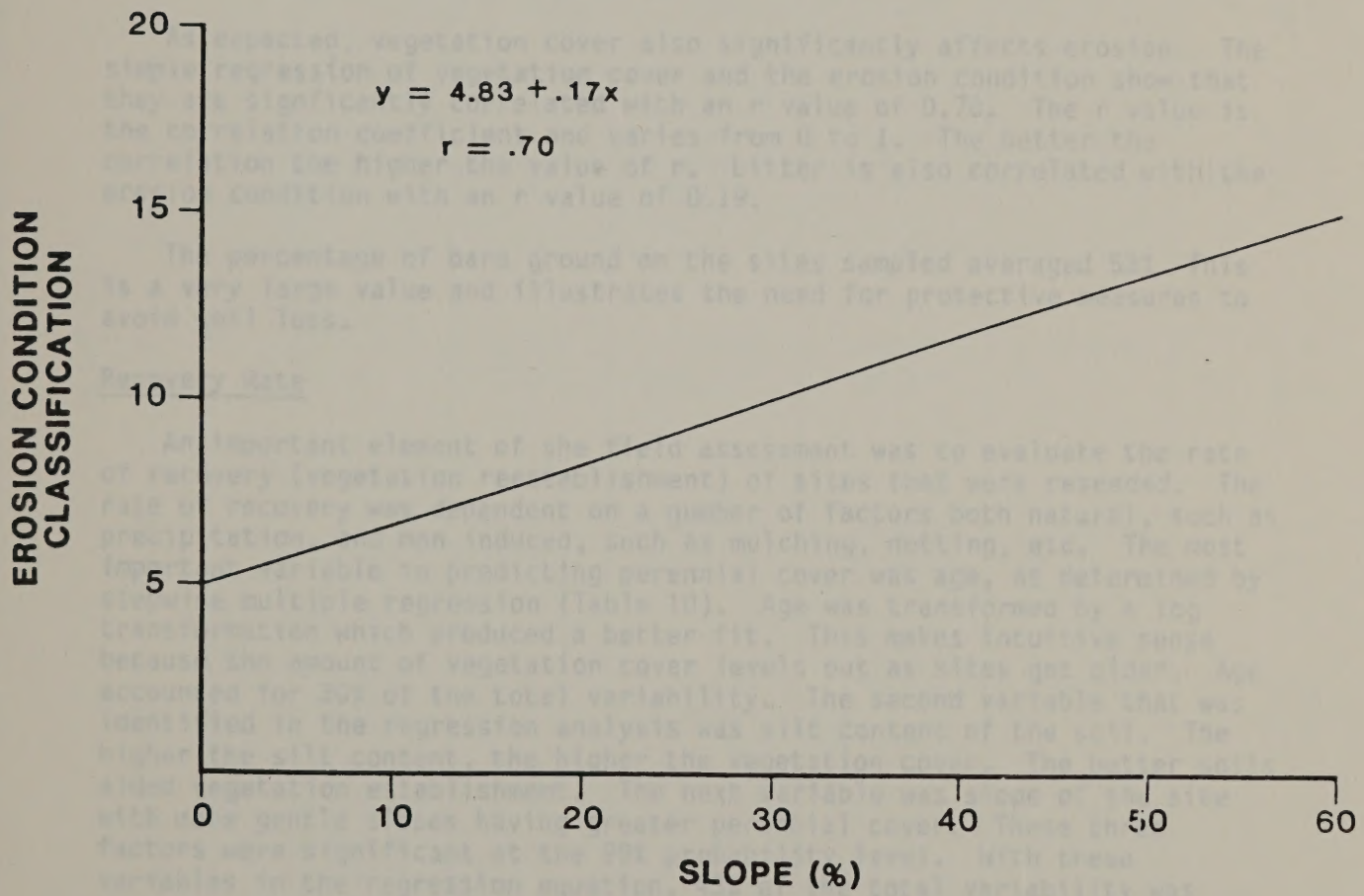
Table 8. Stepwise multiple regression analysis for erosion condition classification

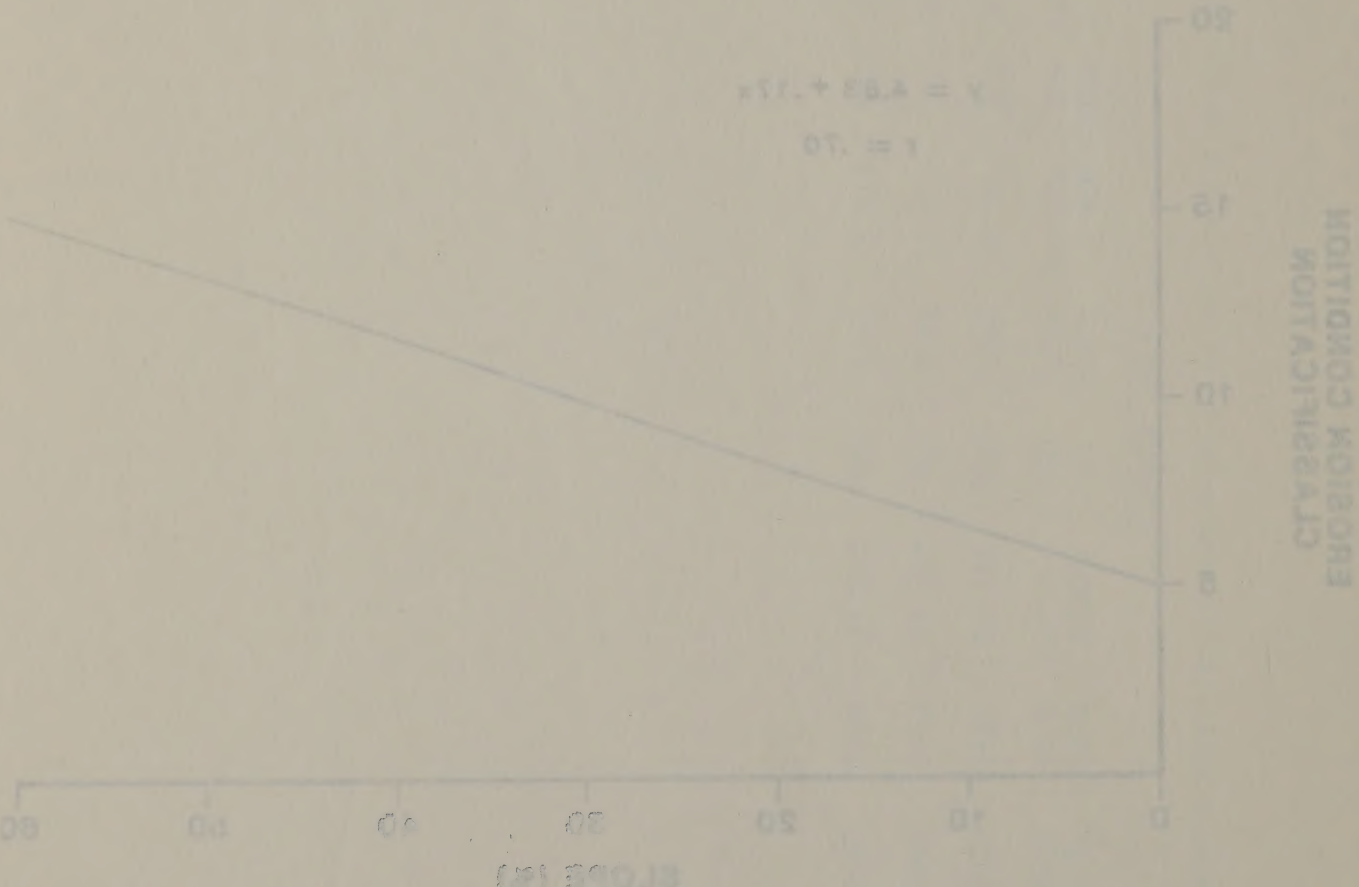
SUMMARY TABLE

STEP	MULTR[1]	RSQ[2]	ADJRSQ	F(EQU)	SIGF	RSQCH	FCH	SIGCH		VARIABLE	BETAIN	CORREL
1	.6963	.4848	.4814	142.081	.000	.4848	124.081	.000	IN:	SLOPE	.6963	.6963
2	.7293	.5318	.5256	85.192	.000	.0470	15.067	.000	IN:	ROCK	-.2185	-.1296
3	.7527	.5665	.5578	64.906	.000	.0347	11.925	.001	IN:	TOTAL COVER	-.1967	-.3604
4	.7618	.5803	.5690	51.164	.000	.0138	4.873	.029	IN:	SILT	-.1228	-.1919

[1] Multipled by r
[2] r squared

Figure 11. Regression of slope and erosion condition classifications. The regression is significant at $\alpha \leq .01$.




EROSION CONDITION
CLASSIFICATION
0
5
10
15
20

should be avoided where possible. Where they are necessary special erosion control features such as netting should be considered. Erosion on slopes less than 10% was usually minor and was generally controlled by techniques such as contour ripping and seeding. Slopes from 11-20% needed more care but erosion was generally controlled by contour ripping and a few carefully constructed water bars. The majority of the water control problems were associated with slopes steeper than 20%. These areas needed carefully constructed water bars.

Erosion control can be effective on steep slopes. Slopes at the Carter Creek and Anschutz plant sites are good examples of proper erosion control when steep slopes are necessary (Figures 12 and 13). These slopes ranged from 31% to 70% and erosion was classified as stable to slight. These sites were topsoiled, seeded and mulched, with steeper areas netted in order to keep the mulch in place. Water control methods were effectively used.

As expected, vegetation cover also significantly affects erosion. The simple regression of vegetation cover and the erosion condition show that they are signficantly correlated with an r value of 0.70. The r value is the correlation coefficient and varies from 0 to 1. The better the correlation the higher the value of r. Litter is also correlated with the erosion condition with an r value of 0.19.

The percentage of bare ground on the sites sampled averaged 53% This is a very large value and illustrates the need for protective measures to avoid soil loss.

Recovery Rate

An important element of the field assessment was to evaluate the rate of recovery (vegetation reestablishment) of sites that were reseeded. The rate of recovery was dependent on a number of factors both natural, such as precipitation, and man induced, such as mulching, netting, etc. The most important variable in predicting perennial cover was age, as determined by stepwise multiple regression (Table 10). Age was transformed by a log transformation which produced a better fit. This makes intuitive sense because the amount of vegetation cover levels out as sites get older. Age accounted for 30% of the total variability. The second variable that was identified in the regression analysis was silt content of the soil. The higher the silt content, the higher the vegetation cover. The better soils aided vegetation establishment. The next variable was slope of the site with more gentle slopes having greater perennial cover. These three factors were significant at the 99% probability level. With these variables in the regression equation, 43% of the total variability was accounted for. The 57% of the variability was due to factors that were not included in the analyses such as mulching, site preparation, seed mix, precipitation in the year of seeding, etc.

This multiple regression analysis demonstrates that there are numerous other factors that can influence perennial cover. Many of these factors can be manipulated with effective management of the resources available onsite (Figure 14). They do require planning and careful coordination among the contractors developing a site. For example, topsoil salvage can

Table 9. The number of subsites categorized by slope and erosion condition class.

Erosion Class		SLOPE (%) (0-10) 1	(11-20) 2	(21-30) 3	(31-40) 4	(41-50) 5	> 50 6	ROW TOTAL
Stable	COUNT	34	6	0	0	0	0	40
	ROW PCT	85.0	15.0	.0	.0	.0	.0	100.0
	COL PCT	57.6	17.1	.0	.0	.0	.0	
	TOT PCT	22.2	3.9	.0	.0	.0	.0	26.1
Slight		20	18	8	5	3	0	54
		37.0	33.3	14.8	9.3	5.6	.0	100.0
		33.9	51.4	29.6	27.8	42.9	.0	
		13.1	11.8	5.2	3.3	2.0	.0	35.3
Moderate		5	8	10	6	1	1	31
		16.1	25.8	32.3	19.4	3.2	3.2	100.0
		8.5	22.9	37.0	33.3	14.3	14.3	
		3.3	5.2	6.5	3.9	.7	.7	20.3
Critical		0	3	9	6	3	4	25
		.0	12.0	36.0	24.0	12.0	16.0	100.0
		.0	8.6	33.3	42.0	57.1		
		.0	2.0	5.9	3.9	2.0	2.6	16.3
Severe		0	0	0	1	0	2	3
		.0	.0	.0	33.3	.0	66.7	100.0
		.0	.0	.0	5.6	.0	28.6	
		.0	.0	.0	.7	.0	1.3	2.0
COLUMN TOTAL		59	35	27	18	7	7	153
		100.0	100.0	100.0	100.0	100.0	100.0	100.0
		38.6	22.9	17.6	11.8	4.6	4.6	100.0

Figure 12. Excellent vegetation cover and erosion control of steep slopes at Chevron's Carter Creek Plant.

Figure 13. Excellent vegetation cover and erosion control of steep slopes at Amoco's Niject Plant road.

Table 10. Stepwise multiple regression analysis for cover of perennial species.

SUMMARY TABLE

STEP	MULTR	RSQ	ADJRSQ	F(EQU)	SIGF	RSQCH	FCH	SIGCH	VARIABLE	BETAIN	CORREL
1	.5517	.3044	.2998	66.067	.000	.3044	66.067	.000	IN: LOG	.5517	.5517
2	.6380	.4071	.3992	51.495	.000	.1027	25.988	.000	IN: SILT	.3281	.1949
3	.6562	.4306	.4191	37.561	.000	.0235	6.155	.014	IN: SLOPE	-.1550	-.2201

greatly expedite recovery because this practice retains the better (silty) soils (Figure 15).

A simple regression analysis between age and perennial cover is shown in Figure 16. It shows that in 3 years the average cover of a site would be 19%, and in ten years the cover would be 31%. The relationship between age and cover is not very good, but again, this is because other factors play such important roles. The Anschutz plant site and Carter Creek plant site are two good examples. Cover ranged from 35-70% after only two years. This reflects the good reclamation techniques that were used, coupled with years of good precipitation.

Dominant Species

The most common species occurring on the reseeded areas sampled are listed in Table 11. Seeded and nonseeded species are included in this list. Seeded species represented nine of the top ten most common species. The most common species was crested wheatgrass which occurred on 63% of the sites. Wheatgrasses comprise 4 of the top 5 species and 6 of the top 10. There was one shrub, big sagebrush, represented in the top 10. This species occurred on 43% of the sites. Likewise there was only one forb, alfalfa, which occurred on 24% of the sites. Smooth brome and foxtail barley were the only two non-wheatgrass grasses that were in the top 10. Numerous other species were included in seed mixes but they were present on only a very few sites.

Invading Species

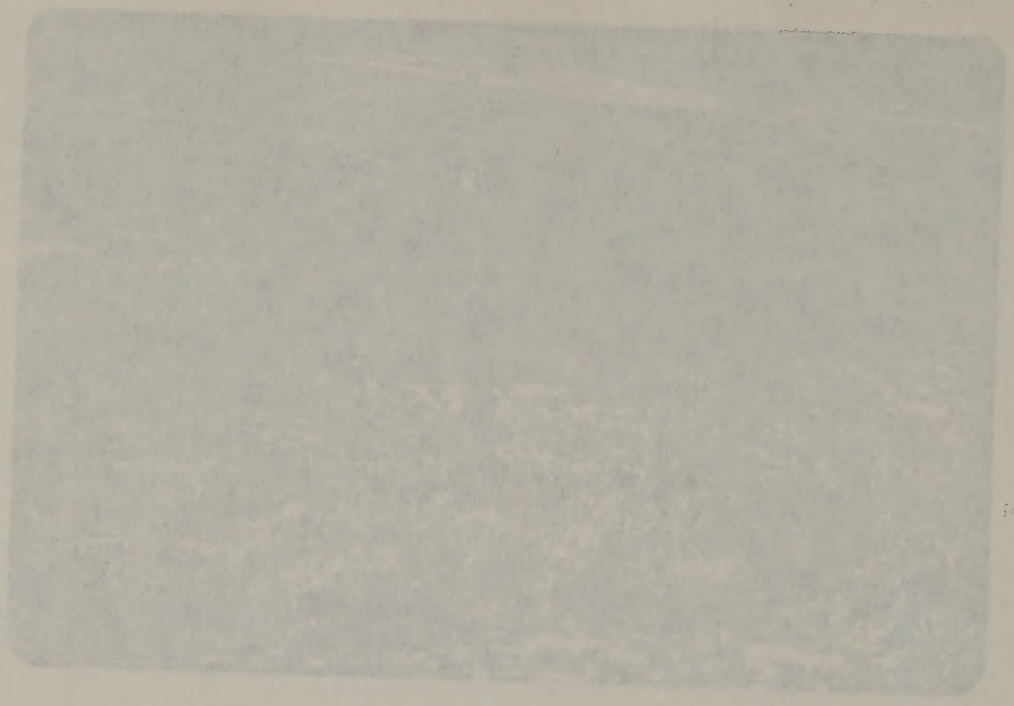
The major species that were not seeded but have invaded naturally were: big sagebrush, occurring on 43% of the sites; Douglas rabbitbrush and yarrow, both on 17%; rubber rabbitbrush, 12%; aster and snowberry, both on 11%; locoweed and bluebunch wheatgrass, both on 7%; and penstemon, 6%. Many more occurred on less than 10 sites of the 176 total sites. Detailed descriptions of the occurrence of these species are found in Appendix 3.

Natural invasion appeared to be a slow process but did occur on many of the older sites (Figures 17 and 18). Sites with minimal disturbance had greater invasion of nonplanted species. Areas along pipelines that were only bladed and were not extensively disturbed had much greater invasion especially from rhizomatous and sprouting plant parts. The Exxon pipeline along the summit of the Bear River Divide was one example (Figure 19 and 20). Portions of drill sites that were only scraped also had rapid reinvasion.

An interesting technique that increased shrub reinvasion was the use of water bars. These areas were often not seeded, particularly if the site was drill seeded, as generally the drill would be pulled more or less parallel to the slope which was also parallel to the water bars. The water bar would be skipped because of the uneveness in the terrain leaving a strip several feet wide that was not seeded to the conventional grass dominated mixture. In other cases, water bars would be cut into already established vegetation. Shrub invasion was accelerated along waterbars, mainly because of the decreased competition from the grasses. This approach of leaving unseeded strips was purposefully implemented on a site in the Painter Area (Figures 21-22). Perennial vegetation cover on the

Figure 14. Effective reestablishment of aspen caused by leaving root materials intact when clearing a site.

Figure 15. Excellent vegetation establishment by utilizing topsoil.



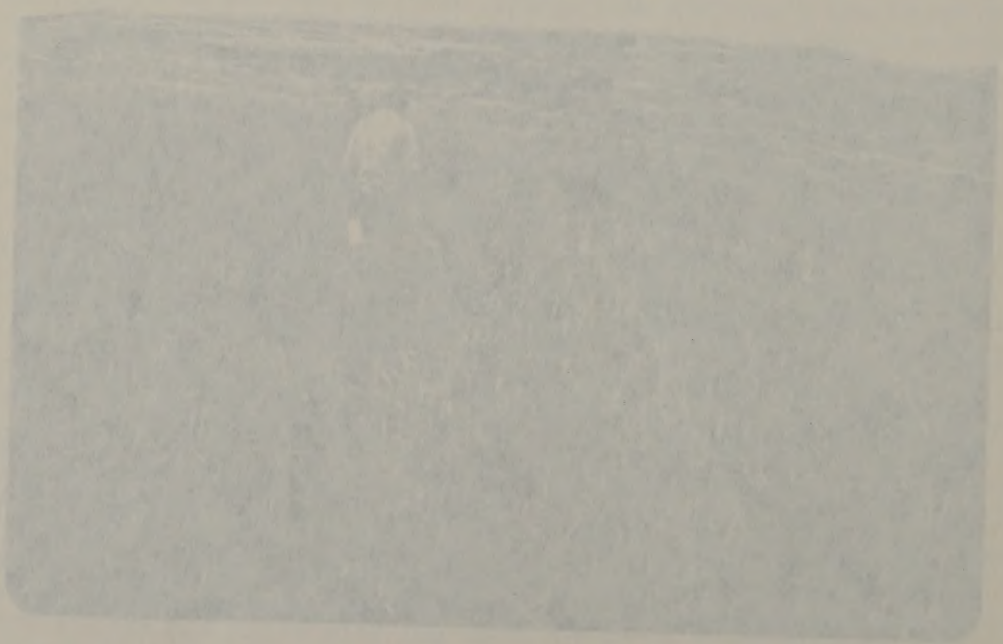
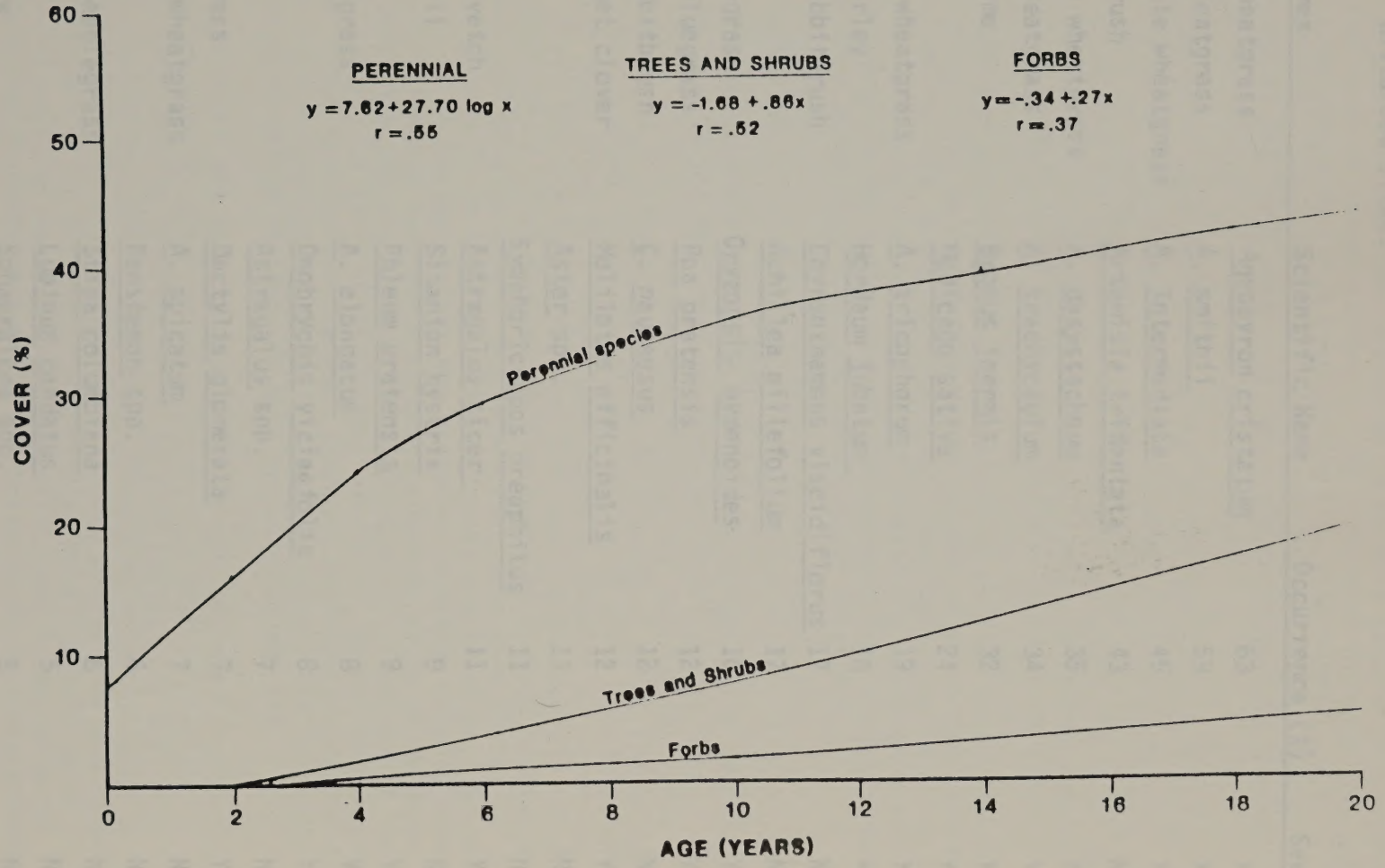


Figure 16. Regression of age and cover for perennial species, trees ans shrubs and forbs. All regressions are significant at $\alpha \leq .01$



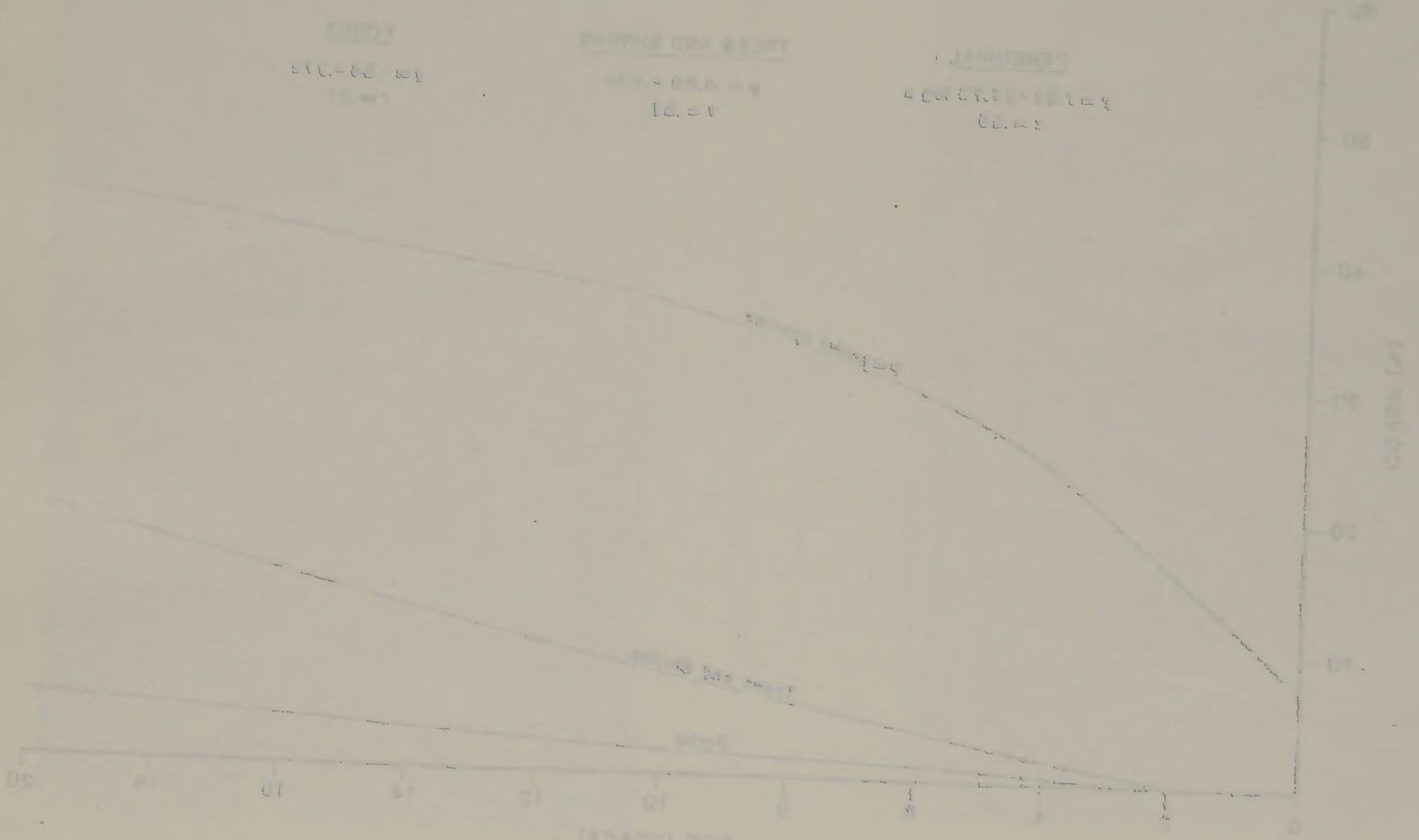


Table 11. List of the most common species occurring on the disturbed sites.

Common Names	Scientific Name	Occurrence (%)	Seeded
crested wheatgrass	Agropyron cristatum	63	Y
western wheatgrass	A. smithii	59	Y
intermediate wheatgrass	A. intermediate	45	Y
big sagebrush	Artemisia tridentata	43	N
thickspike wheatgrass	A. dasystacheum	35	Y
slender wheatgrass	A. trachycaulum	34	Y
smooth brome	Bromus inermis	32	Y
alfalfa	Medicago sativa	24	Y
pubescent wheatgrass	A. tricophorum	19	Y
foxtail barley	Hordeum jubatum	18	*
Douglas rabbitbrush	Chyrsothamnus viscidiflorus	17	N
yarrow	Achillea millefolium	17	N
Indian ricegrass	Oryzopsis hymenoides	16	Y
Kentucky bluegrass	Poa pratensis	12	Y
rubber rabbitbrush	C. nauseosus	12	N
yellow sweet clover	Melilotus officinalis	12	Y
aster	Aster spp.	11	N
Snowberry	Symphoricarpos oreophilus	11	N
Cicer milkvetch	Astragalus cicer	11	Y
squirreltail	Sitanion hystrix	9	N
timothy	Phleum pratensis	9	Y
tall wheatgrass	A. elongatum	8	Y
sainfoin	Onobrychis viciaefolia	8	Y
locoweed	Astragalus spp.	7	N
orchard grass	Dactylis glomerata	7	Y
bluebunch wheatgrass	A. spicatum	7	N
penstemon	Penstemon spp.	6	N
Columbia needlegrass	Stipa columbiana	6	N
lupine	Lupinus candatus	5	N
globemallow	Sphaeralcea spp.	5	N

* Seed is often inadvertantly included in the mulch but not in the seed mix.

Table 11. List of the most common species occurring on the disturbed sites.

Common Name	Scientific Name	Occurrence (%)
crested wheatgrass	Agropyron cristatum	83
western wheatgrass	A. smithii	77
intermediate wheatgrass	A. intermedium	46
big sagebrush	Artemisia tridentata	43
thickspike wheatgrass	A. dasystachyum	30
slender wheatgrass	A. trachycaulum	29
smooth brome	Bromus inermis	24
alfalfa	Medicago sativa	19
pubescent wheatgrass	A. trichophorum	17
foxtail barley	Hordeum jubatum	16
Douglas rabbitbrush	Chrysothamnus viscidiflorus	12
yarrow	Achillea millefolium	12
Indian ricegrass	Oryzopsis hymenoides	11
Kentucky bluegrass	Poa pratensis	10
rubber rabbitbrush	C. nauseosus	10
yellow sweet clover	Melilotus officinalis	10
aster	Aster spp.	9
snowberry	Symphoricarpos occidentalis	9
Cicer milkvetch	Astragalus cicer	8
squirreltail	Sitanion hystrix	8
timothy	Phleum pratensis	8
tall wheatgrass	A. elongatum	7
saltbush	Chenopodium virgaceum	7
locoweed	Astragalus spp.	7
orchard grass	Dactylis glomerata	7
bluebunch wheatgrass	A. spicatum	7
penstemon	Penstemon spp.	6
Columbia needlegrass	Stipa columbiana	6
lupine	Lupinus caudatus	5
globemallow	Sphaeralcea spp.	5

* Seed is often inadvertantly included in the mulch but not in the seed mix.

4-year-old site was lower on the nonseeded strips (5-12%) than on the seeded strips (25-27%) but forb and shrub cover were greater on nonseeded strips (4-10%) than on seeded strips (< .3%). Species richness was also greater on nonseeded areas (9.5 species) than on seeded areas (5.5 species). Although these strips do encourage invasion, they should be kept narrow because of the lower amount of cover and consequently, greater potential for erosion.

A multiple regression analysis was run on the percentage of shrub species invading different sites to identify other factors that might accelerate their invasion. The main variable entering the regression was age, which accounted for 27% of the variability. Only one other variable was significant and that was the percentage of rock, which had a negative correlation. A summary table of the main factors is given in Table 12.

A similiar regression was run on the cover of native forbs reinvading the disturbances. The main variable entering this equation was also age, which accounted for 14% of the variability. Other variables entering this equation were elevation and adjusted aspect (Table 13). Higher elevation and more northeast-facing slopes appeared to enhance forb invasion, both of which favor more moist conditions and better water relations.

Mulches and Netting

One of the reasons for the large variability in perennial cover among the sites was due to the different reclamation techniques utilized. This was particularly true with the various mulches and netting that were applied on the steeper slopes. Evidence of the use of mulch and netting has been fairly limited in the Overthrust Belt area until recently, despite the fact that many sites have very steep slopes. Results of reseeding success on areas where mulch or netting were applied are varied. Where properly installed on steep slopes, netting resulted in good vegetation establishment and erosion condition classes that were excellent. On comparable slopes with no netting serious erosion had occurred. On areas that were not as steep, mulch that was properly tacked or crimped worked effectively. On nearly flat surfaces mulch appeared to be of no added benefit except on sites with poor or limited topsoil. Examples of the use of jute, burlap, nylon mesh, plastic mesh, excelsior, straw, hydromulch and annual cover crops were evident. Burlap appeared ineffective because its tight weave limited vegetation growth. Although netting can be quite effective in controlling erosion, it must be properly applied.

The use of mulch and netting does not preclude the use of proper water control devices such as water bars and berms, but must be used in conjunction with them to be effective. In some cases, jute was ineffective; but it was improperly installed and water was allowed to run over the slope from the pad above. Jute is more costly than the other types of netting. It is difficult to properly install but is quite durable. Other nettings appeared to be as effective, if not more so. Properly installed nettings were still effective in controlling erosion after 2-3 years. Plastic netting (e.g., Conwed) has begun deteriorating after 1 year and should be fairly indistinquishable 3 years following installation. This netting is the least durable. Hydromulch when used alone, appeared less effective than straw, if the straw was anchored in

Figure 17. An old site (20 years) near LaBarge, Wyoming, that had little or no reclamation.

Figure 18. A twenty year old site near Afton, Wyoming. Natural invasion was slow due to lack of soil.

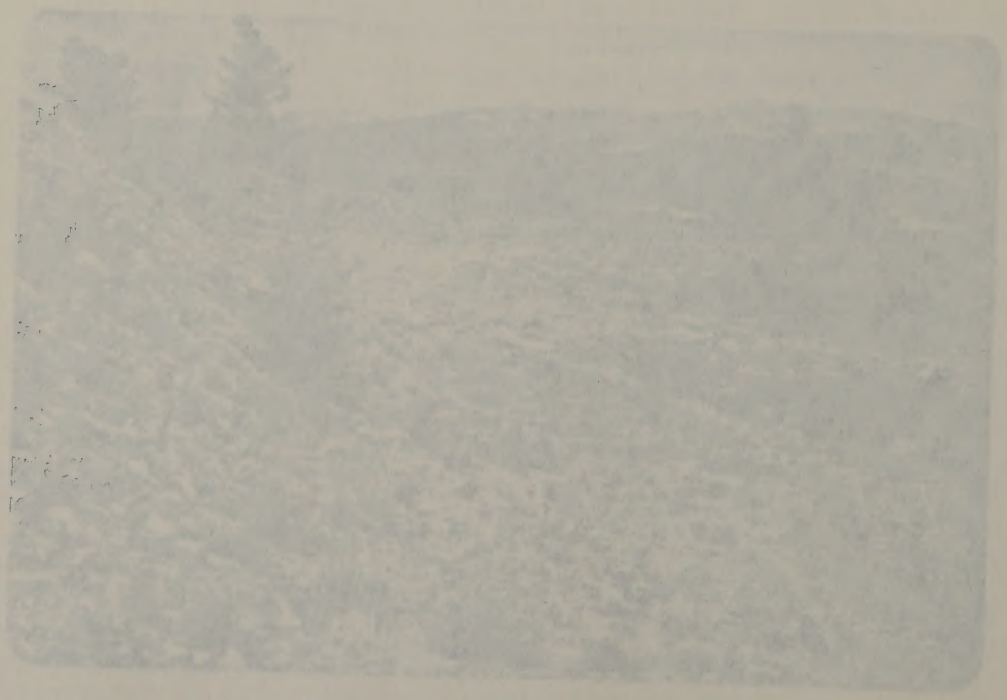
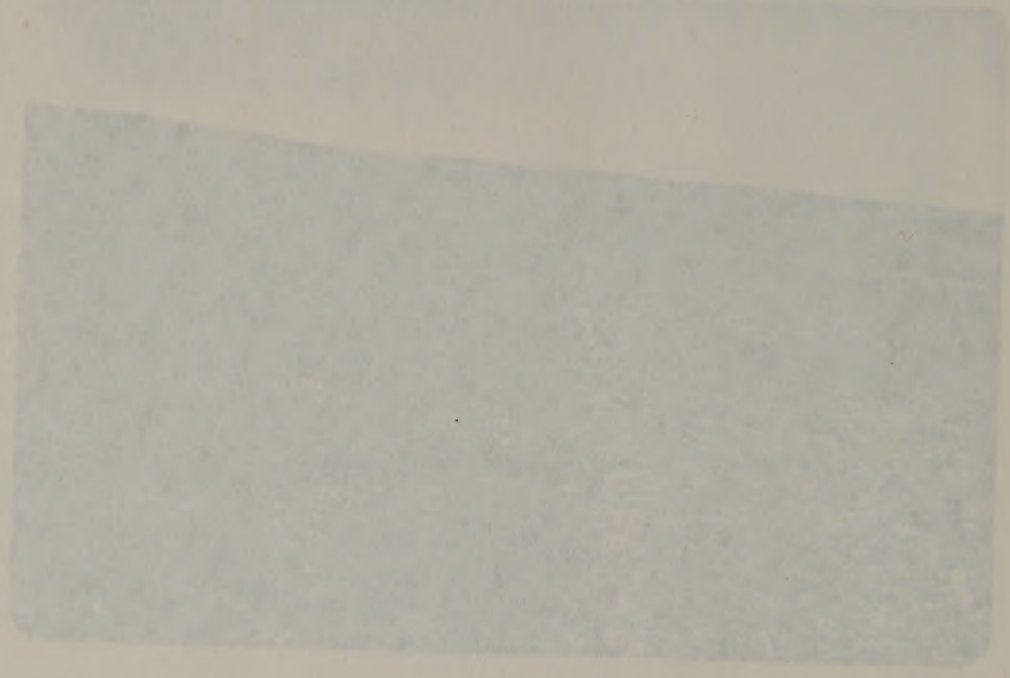


Figure 19. A pipeline that was constructed by just scraping off the vegetation and not removing soil except where the pipe was laid. Natural invasion was excellent on this site.

Figure 20. A pipeline where the entire right of way was disturbed and seeding success was poor.



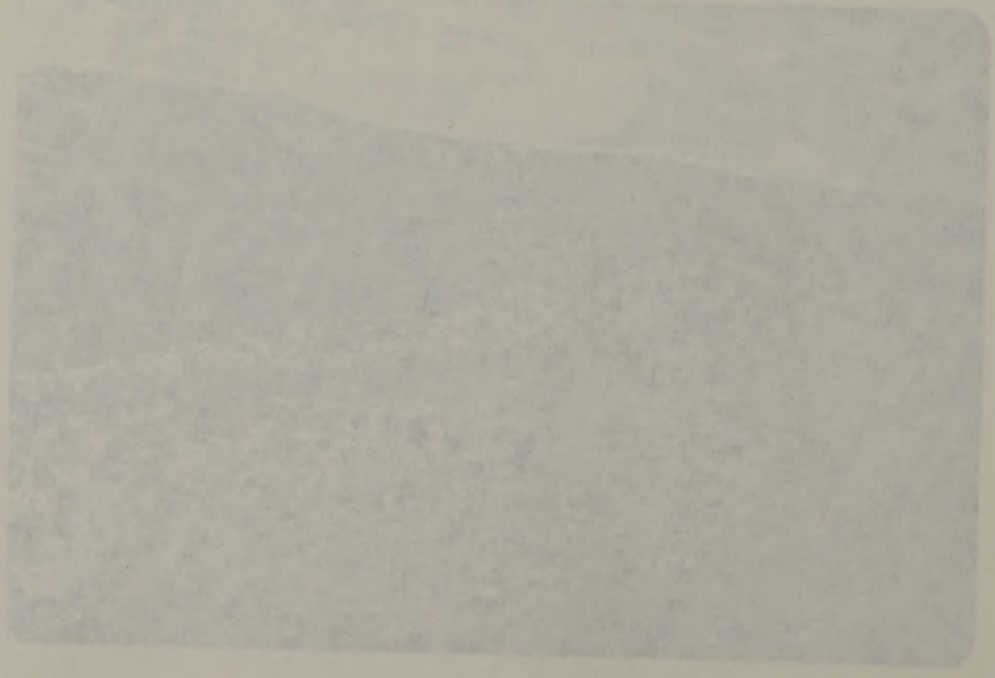


Figure 21. A site showing natural reinvasion of woody species onto an area that was not seeded.

Figure 22. Invasion of native species into strips that were not seeded.

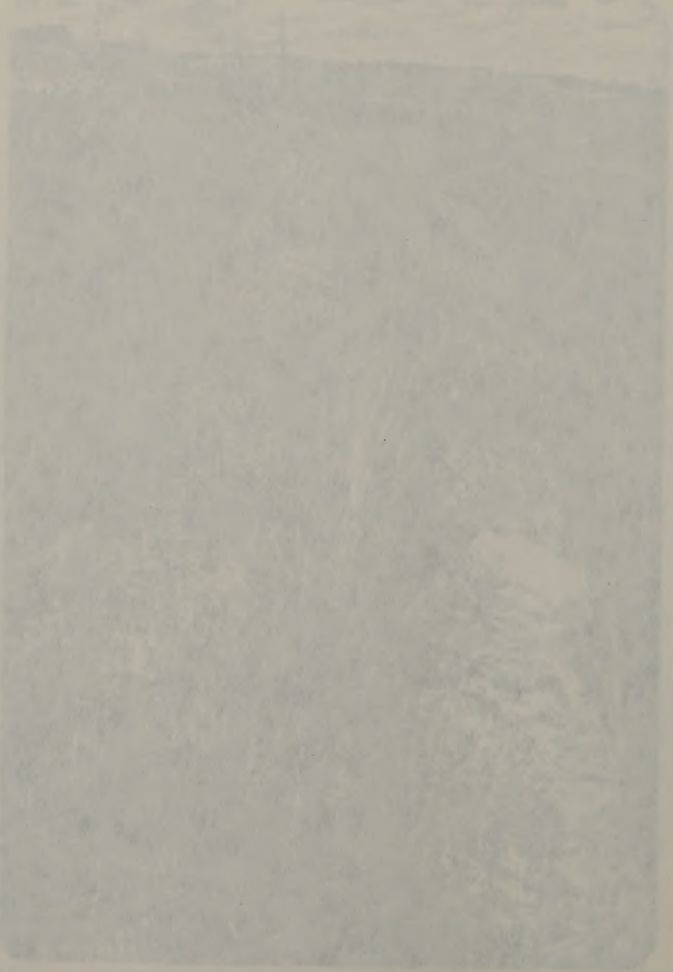


Table 12. Stepwise multiple regression analysis for cover of woody species.

SUMMARY TABLE

STEP	MULTR	RSQ	ADJRSQ	F(EQU)	SIGF	RSQCH	FCH	SIGCH		VARIABLE	BETAIN	CORREL
1	.5192	.2695	.2647	55.716	.000	.2695	55.716	.000	IN:	AGE	.5192	.5192
2	.5482	.3006	.2912	32.231	.000	.0310	6.658	.011	IN:	ROCK	-.1815	-.0464

Table 13. Stepwise multiple regression analysis for cover of forbs.

SUMMARY TABLE

STEP	MULTR	RSQ	ADJRSQ	F(EQU)	SIGF	RSQCH	FCH	SIGCH		VARIABLE	BETAIN	CORREL
1	.3713	.1379	.1322	24.150	.000	.1379	24.150	.000	IN:	AGE	.3713	.3713
2	.4141	.1715	.1605	15.525	.000	.0336	6.086	.015	IN:	ELEVATION	.1848	.2280
3	.4426	.1959	.1797	12.098	.000	.0244	4.517	.035	IN:	ADJUSTED ASPECT	-.1593	-.0997

place. This is probably due to the short fiber length in the hydromulch. In either case, straw or hydromulch lasted approximately one year. One site had used an annual cover crop for a mulch. It was fairly ineffective however, as a good stand of annual cover had not been achieved, possibly from the lack of precipitation while the seed was germinating. An annual stubble mulch does have potential on gentler slopes but requires monitoring and an alternative method if the cover crop fails.

Test plots at Amoco's Anschutz Ranch East Production Facility were installed in 1983 to assess the importance of various techniques including mulching. Results showed that on steep southwest-facing, non-topsoiled slopes, mulch with tack was quite effective at increasing cover and density and decreasing erosion (Table 14). Mulch that was blown onto the slope without tack was not as effective since most of the mulch was blown off from the strong winds that are characteristics of the area, but was still significantly better than no mulch at all. Total cover increased over 300% on the mulched and tacked treatments compared to the no mulch treatment and over 160% compared to the mulch with no tack. Plant density showed not as dramatic a difference, with the mulch and tack treatments increasing density 180% and 150% above the no mulch and mulch with no tack respectively.

Soil loss was significantly reduced by the application of mulch and tack. Soil loss was measured by erosion pins as described by Toy (1983). This technique involves placing a metal rod into the soil and marking the soil line on the rod. After a given period of time, a measurement is taken from the original mark to the soil surface with the difference representing the amount of soil lost. The last column in Table 14 represents the amount of soil lost over an 18 month period. The no mulch treatment had an erosion pin measurement over 4 times that of the mulch and tack treatment and 2 times that of the mulch without tack treatment.

On an adjacent north-facing, topsoiled slope that was more gentle (15%), mulch had no significant effect on vegetation cover or density. It did, however, appear to have an effect on soil erosion. The mulched and tacked sites tended to have less erosion, although the difference was not statistically significant due to large variability of the data (Table 15). The soil was protected by mulch during the period prior to vegetation establishment. Mulch would be very important for erosion control on areas that are fall seeded or left unvegetated during the winter period.

The Chevron's Carter Creek Production provided a comparison of the effects of different types of netting. Three different netting materials were used on steep east-facing slopes. These included jute, excelsior, and hay plus Conwed netting. The different netting all performed equally well on erosion condition classifications showing no visual signs of erosion. The excelsior appeared to favor vegetation establishment with a slightly higher perennial vegetation cover of 40% compared to 30% for jute and 25% for hay and Conwed. Samples were not replicated so no statistical comparison could be made between treatments. These cover values are exceptionally good considering that the slopes are very steep (45%) and the vegetation has had only two growing seasons prior to sampling (Figure 12).

Table 14. Summary table of results for west facing test plots at Amoco Anschutz Production Plant site. Data was gathered in August of 1984. Means followed by a common letter are not significantly different as tested by ANOVA and LSD mean separation tests ($\alpha \leq .05$).

Treatment	Density/m^2	Cover (%)	Erosion (mm)
No mulch	28.9^a	7.5^a	8.0^a
Mulch, no tack	33.8^b	16.3^b	4.2ab
Mulch, tack	51.8^c	26.7^c	1.9^b

Topsoil

Another important factor in enhancing vegetation reestablishment is the use of topsoil. Only a limited analysis of the effectiveness of topsoil was possible from this sampling since there were only four sites that had comparative areas that were clearly topsoiled and not topsoiled. In every case the topsoiled area had higher perennial cover, total cover, number of species present and a better erosion condition classification (Figures 23-24). Paired-t analysis showed that only total cover was statistically different at the 95% probability level but definite trends exist for the other factors as well. The other factors, perennial cover, number of species and erosion classification, were significant between the 90 and 95% level (Table 16). The importance of topsoil cannot be overemphasized. The presence of silt and rock in many of the multiple regressions indicate that good topsoil heavily influences vegetation cover, including shrub establishment.

Weeds

Ten major weeds were identified on the sites sampled. These are shown in Table 17 by state of occurrence. The dominant weed species included the thistles (canadian, elk and musk), knotweed, Russian thistle, pigweed, cheatgrass, pennycress, henbane and halogeton. Weed problems varied among sites with some sites being almost entirely weeds (Figure 25). Weed cover generally declined after perennial vegetation was established. Several of these weeds are classified as "noxious" by the states involved. Thus it is important to deal with weed problems quickly before the seed is spread to nearby disturbed sites. Musk thistle is an example of a noxious weed that is spreading throughout the Overthrust Belt area. It was not found in the area at all several years ago. Henbane which was generally restricted to Utah, has also spread extensively the past few years.

Grazing

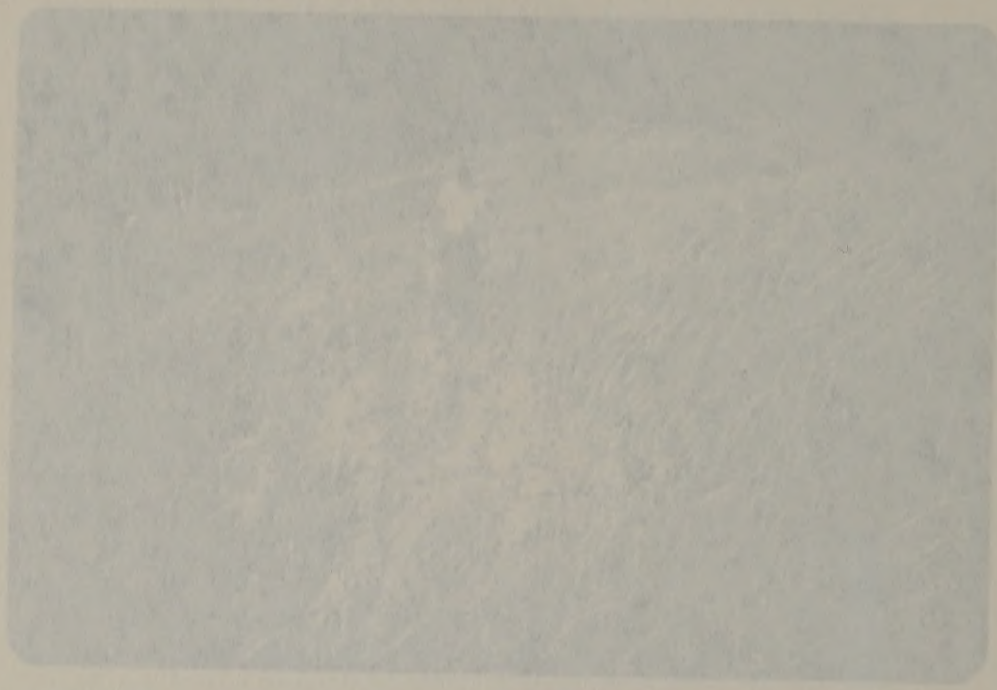
Only one site provided a good control/treatment type of analysis on the effects of grazing since very few sites were fenced. The site was Chevron's Carter Creek production facility (Figure 26), which was seeded in 1983. Two subsites, one with steep slopes (45%) and one with almost no slope (1%) were inside the fence and two were outside, one with 34% slopes and one with 1% slopes. The ungrazed steep subsite averaged 35% cover with an erosion condition value of 5.0 (slight), while the grazed site averaged 10% cover with an erosion condition value of 9.0 (moderate). The ungrazed flat subsite averaged 65% cover while the grazed subsite averaged 20% cover. Both sites had erosion condition values of 4.0 (stable). In both cases the nongrazed subsites had over 3 times the cover of the grazed plots. This cover was important in reducing erosion on steeper slopes.

Table 15. Summary table of results for the north-facing plots at Amoco's Anschutz Production facility. Data was gathered in August of 1984. Means followed by common letters are not significantly different as tested by ANOVA and LSD mean separation tests ($\alpha \leq .05$).

Treatments	Density/m^2	Cover (%)	Erosion (mm)
No mulch	44.2[a]	44.5[a]	4.8[a]
Mulch, no tack	50.4[a]	40.3[a]	2.3[a]
Mulch, tack	41.0[a]	40.0[a]	0.9[a]

Figure 23. Site showing effects of topsoil on vegetation cover (left of person) compared to non-topsoiled area (lower right portion of photo).

Figure 24. Photo showing the effects of topsoil. The upper steeper slope was topsoiled while the lower slope was not topsoiled.



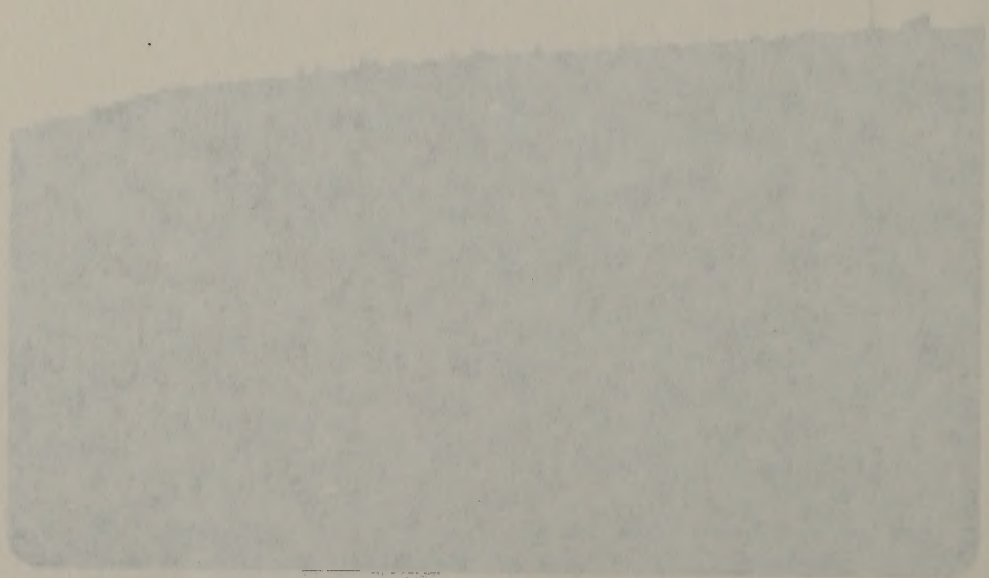
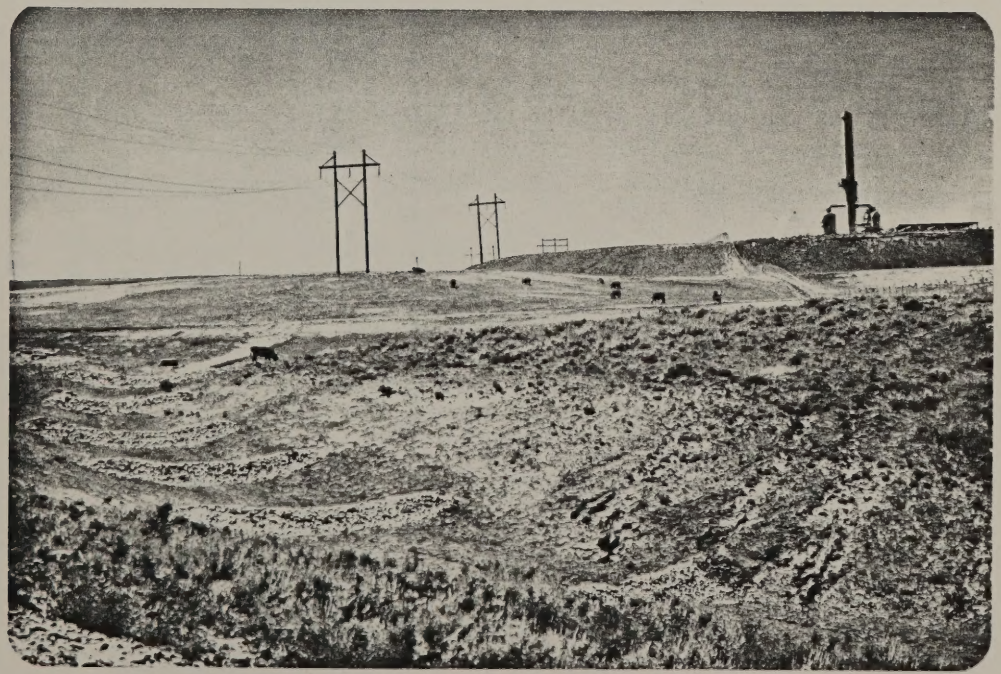
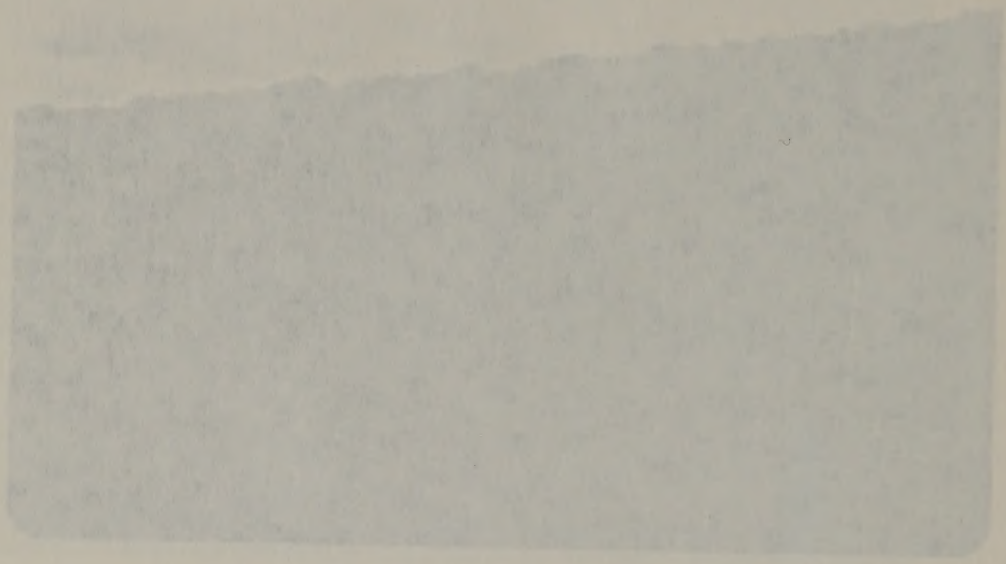


Figure 25. Site that was infested with Canadian thistle. Little or no reclamation was apparent on the site.

Figure 26. Photo showing the effects of grazing on plant cover. The upper slopes on the right served as the comparison of effects.





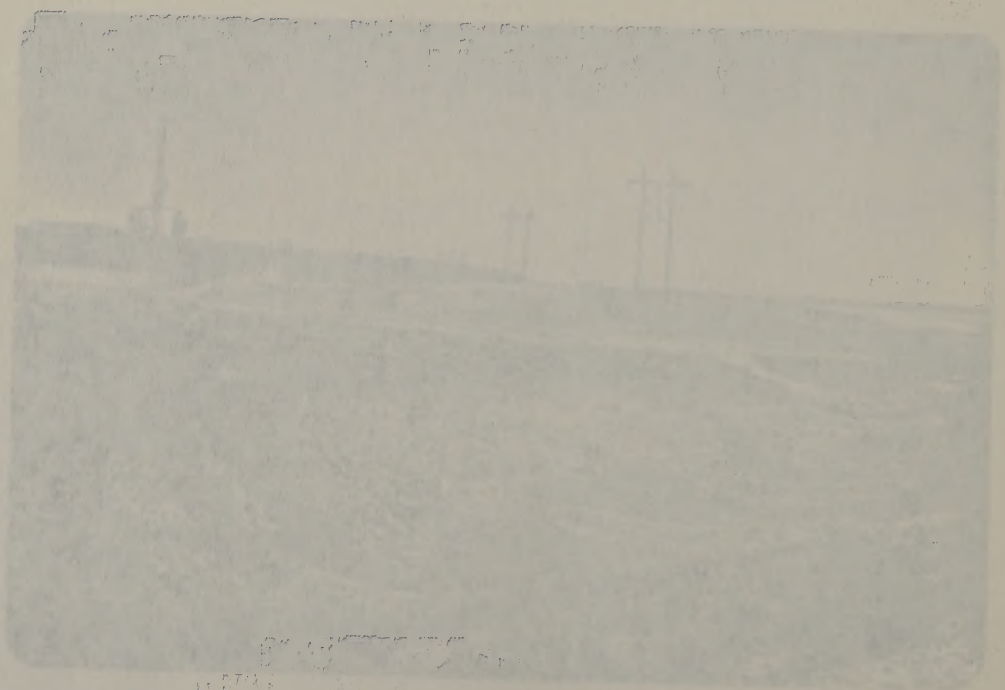


Table 16. The paired t analysis for sites with and without topsoil.

	x	df	d	sd	t
Total Cover					
topsoil	26.75	3	16.25	9.6	3.38*
untopsoil	11.0				
Perennial Cover					
topsoil	21.5	3	13.5	9.29	2.91
nontopsoil	8.0				
Erosion Classification					
topsoil	7.5	3	3.5	2.65	2.65
nontopsoil	11.0				
Number of Species					
topsoil	7.75	3	3.0	2.16	2.78
nontopsoil	4.75				

*$\alpha \leq .05$

Table 17. Commonly occurring weeds in the 176 subsites sampled and the states in which they occurred.

	Idaho	Utah	Wyoming	Total	%
cheatgrass	0	9	28	37	21
pigweed	0	3	35	38	22
thistles (Canadian,musk)	9	13	57	79	45
henbane	0	4	2	6	3
halogeton	0	1	3	4	2
Russian thistle	0	8	34	42	24
knotweed	2	4	51	57	32
pennycress	0	4	21	25	14

CONCLUSIONS

Several conclusions can be made from the field assessment regarding appropriate techniques that could improve reclamation success. These conclusions are:

- Water management on site was the most serious problem observed and is a critical factor in reducing erosion.

- Erosion control becomes increasingly important as slope increases. Reconstruction should utilize gentle slopes wherever possible. Successful revegetation of steep slopes is possible, but effective water control is mandatory and mulching or netting is advisable, depending upon the slope and critical nature of the site.

- Grazing is a common problem and should be reduced or eliminated during the initial year following seeding if possible.

- Appropriate reclamation techniques, i.e., ripping, mulching, netting, etc., are effective when utilized correctly, and greatly enhance vegetation establishment as well as reduce erosion.

- Reclamation goals should be established prior to any disturbance and assessment of those goals needs to be implemented as part of a compliance program.

- A monitoring and maintenance program needs to be established to correct minor reclamation problems before they escalate to major problems.

- Natural invasion onto disturbed sites was generally slow but was enhanced where disturbances could be minimized or limited to scraping. Leaving narrow unseeded strips greatly augmented shrub reinvasion, particularly if topsoil was present.

- The use of topsoil dramatically enhances vegetation establishment.

- Concern should be given to the control of weeds on some sites.

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APPENDICES

APPENDIX 1. List of plant names and symbol codes used in this report.

APPENDIX 2. Analysis by vegetation type for total cover, perennial cover, shrub cover, forb cover, total invaders cover, litter cover, rock cover, bare ground and erosion condition classification.

APPENDIX 3. Analysis of species by vegetation type.

APPENDIX 4. List of raw data.

APPENDIX 5. Analysis of variance comparing production facilities reclamation with all other sites.

APPENDIX 1. LIST OF PLANT NAMES AND SYMBOL CODES USED IN THIS REPORT.

COMMON NAME	SCIENTIFIC NAME	SYMBOL CODE
alfalfa	*Medicago sativa*	MESA
aster	*Aster spp.*	ASTER
big sagebrush	*Artemesia tridentata*	ARTR
bluebunch wheatgrass	*Agropyron spicatum*	AGSP
buckwheat	*Eriogonum spp.*	ERIOG
cicer milkvetch	*Astragalus cicer*	ASCI
clover	*Trifolium spp.*	TRIFOL
columbia needlegrass	*Stipa columbiana*	STCO
crested wheatgrass	*Agropyron cristatum*	AGCR
Douglas rabbitbrush	*Chrysothamnus viscidiflorus*	CHVI
foxtail barley	*Hordeum jubatum*	HOJU
gooseberryleaf globemallow	*Spaeralcea grossulariaefolia*	SPGR
Indian ricegrass	*Oryzopsis hymenoides*	ORHY
intermediate wheatgrass	*Agropyron intermediate*	AGIN
Kentucky bluegrass	*Poa Pratensis*	POPR
locoweed	*Astragalus spp.*	ASTRA
lupine	*Lupinus cadatus*	LUCA
mountain brome	*Bromus marginatus*	BRMA
orchard grass	*Dactylis glomerata*	DAGL
penstemon	*Penstemon spp.*	PESP
perennial ryegrass	*Lolium perenne*	LOPE
pubescent wheatgrass	*Agropyron trichophorum*	AGTRI
rubber rabbitgrush	*Chrysothamnus nauseosus*	CHNA
sainfoin	*Onobrychis viciaefolia*	ONVI
scarlet gilia	*Gilia aggregata*	GIAG
silver sagegrush	*Artemesia cana*	ARCA
slender wheatgrass	*Agropyron trachycaulum*	AGTRY
small burnet	*Sanguisorba minor*	SAMI
smooth brome	*Bromus inermis*	BRIN
snowberry	*Symphoricarpos oreophilus*	SYOR
squirreltail	*Sitanion hystrix*	SIHY
tall wheatgrass	*Agropyron elongatum*	AGEL
thickspike wheatgrass	*Agropyron dasystacheum*	AGDA
timothy	*Phleum pratensis*	PHPR
western wheatgrass	*Agropyron smithii*	AGSM
Wood's rose	*Rosa woodsii*	ROWO
yarrow	*Achillea millifolium*	ACMI
yellow sweet clover	*Melilotus officinalis*	MEOF

Appendix 2. Analysis comparing the cover values of vegetation, litter, rock, bare ground, shrub, forb, and shrub plus forb cover, erosion condition classes by vegetation types for all 176 subsites. Cover values are expressed as percentages while erosion classes range from 4-20 with 20 being the most severe erosion.

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE TOTCOVER TOTAL COVER
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			4550.0000	25.8523	16.6140	276.0238	(	176)
TYPE	A	ASPEN	161.0000	26.8333	27.3234	746.5667	(	6)
TYPE	C	CONIFER	248.0000	27.5556	18.8753	356.2778	(	9)
TYPE	G	GRASSLAND	496.0000	24.8000	15.5820	242.8000	(	20)
TYPE	H	SHADSCALE	21.0000	10.5000	13.4350	180.5000	(	2)
TYPE	M	MIXED-SHRUB	563.0000	28.1500	13.7277	188.4500	(	20)
TYPE	P	JUNIPER	595.0000	22.8846	12.2746	150.6662	(	26)
TYPE	S	SAGEBRUSH	2466.0000	26.5161	17.6559	311.7307	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE PERCOVER PERENNIAL COVER
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			3859.0000	21.9261	17.1388	293.7374	(	176)
TYPE	A	ASPEN	159.0000	26.5000	27.3916	750.3000	(	6)
TYPE	C	CONIFER	226.0000	25.1111	19.7576	390.3611	(	9)
TYPE	G	GRASSLAND	353.0000	17.6500	14.7872	218.6605	(	20)
TYPE	H	SHADSCALE	11.0000	5.5000	6.3640	40.5000	(	2)
TYPE	M	MIXED-SHRUB	523.0000	26.1500	15.0448	226.3447	(	20)
TYPE	P	JUNIPER	487.0000	18.7308	13.9128	193.5646	(	26)
TYPE	S	SAGEBRUSH	2100.0000	22.5806	17.8796	319.6809	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE SHRUBCOV
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			236.6090	1.3444	5.7943	33.5743	(	176)
TYPE	A	ASPEN	3.0050	.5008	.7830	.6130	(	6)
TYPE	C	CONIFER	.7400	.0822	.1299	.0169	(	9)
TYPE	G	GRASSLAND	7.6510	.3825	.9765	.9536	(	20)
TYPE	H	SHADSCALE	4.1600	2.0800	2.7294	7.4498	(	2)
TYPE	M	MIXED-SHRUB	86.3230	4.3161	13.4925	182.0479	(	20)
TYPE	P	JUNIPER	5.0840	.1955	.4959	.2460	(	26)
TYPE	S	SAGEBRUSH	129.6460	1.3940	4.8143	23.1774	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE FORBCOV
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			103.9070	.5904	2.5212	6.3566	(	176)
TYPE	A	ASPEN	.6800	.1133	.2406	.0579	(	6)
TYPE	C	CONIFER	12.0330	1.3370	2.3806	5.6674	(	9)
TYPE	G	GRASSLAND	32.0740	1.6037	4.4779	20.0517	(	20)
TYPE	H	SHADSCALE	1.5000	.7500	1.0607	1.1250	(	2)
TYPE	M	MIXED-SHRUB	27.8320	1.3916	5.0606	25.6092	(	20)
TYPE	P	JUNIPER	3.5950	.1383	.3301	.1089	(	26)
TYPE	S	SAGEBRUSH	26.1930	.2816	1.2397	1.5368	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE INVADERS
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			340.5160	1.9347	7.4365	55.3018	(	176)
TYPE	A	ASPEN	3.6850	.6142	.9070	.8227	(	6)
TYPE	C	CONIFER	12.7730	1.4192	2.4244	5.8779	(	9)
TYPE	G	GRASSLAND	39.7250	1.9862	4.8977	23.9875	(	20)
TYPE	H	SHADSCALE	5.6600	2.8300	3.7901	14.3648	(	2)
TYPE	M	MIXED-SHRUB	114.1550	5.7077	18.4302	339.6738	(	20)
TYPE	P	JUNIPER	8.6790	.3338	.6133	.3761	(	26)
TYPE	S	SAGEBRUSH	155.8390	1.6757	5.0230	25.2310	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE LITTER
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			1788.0000	10.1591	13.8175	190.9231	(	176)
TYPE	A	ASPEN	106.0000	17.6667	31.7091	1005.4667	(	6)
TYPE	C	CONIFER	39.0000	4.3333	4.3301	18.7500	(	9)
TYPE	G	GRASSLAND	125.0000	6.2500	9.0022	81.0395	(	20)
TYPE	H	SHADSCALE	1.0000	.5000	.7071	.5000	(	2)
TYPE	M	MIXED-SHRUB	225.0000	11.2500	16.5907	275.2500	(	20)
TYPE	P	JUNIPER	253.0000	9.7308	14.8931	221.8046	(	26)
TYPE	S	SAGEBRUSH	1039.0000	11.1720	12.6230	159.3396	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE ROCK
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			1868.0000	10.6136	16.3654	267.8270	(	176)
TYPE	A	ASPEN	22.0000	3.6667	3.6148	13.0667	(	6)
TYPE	C	CONIFER	347.0000	38.5556	33.7828	1141.2778	(	9)
TYPE	G	GRASSLAND	220.0000	11.0000	18.2064	331.4737	(	20)
TYPE	H	SHADSCALE	30.0000	15.0000	14.1421	200.0000	(	2)
TYPE	M	MIXED-SHRUB	297.0000	14.8500	17.9452	322.0289	(	20)
TYPE	P	JUNIPER	366.0000	14.0769	18.3061	335.1138	(	26)
TYPE	S	SAGEBRUSH	586.0000	6.3011	8.6738	75.2345	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE BARE BARE GROUND
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			9384.0000	53.3182	24.3379	592.3325	(	176)
TYPE	A	ASPEN	311.0000	51.8333	38.8300	1507.7667	(	6)
TYPE	C	CONIFER	266.0000	29.5556	31.5916	998.0278	(	9)
TYPE	G	GRASSLAND	1169.0000	58.4500	18.1673	330.0500	(	20)
TYPE	H	SHADSCALE	148.0000	74.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	915.0000	45.7500	24.8551	617.7763	(	20)
TYPE	P	JUNIPER	1371.0000	52.7308	23.9759	574.8446	(	26)
TYPE	S	SAGEBRUSH	5204.0000	55.9570	22.7165	516.0416	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE TOTSSF EROSION CONDITION CLASSIFICATION
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			1377.0000	7.8239	3.9319	15.4602	(	176)
TYPE	A	ASPEN	67.0000	11.1667	4.6655	21.7667	(	6)
TYPE	C	CONIFER	65.0000	7.2222	3.7676	14.1944	(	9)
TYPE	G	GRASSLAND	120.0000	6.0000	2.7720	7.6842	(	20)
TYPE	H	SHADSCALE	32.0000	16.0000	5.6569	32.0000	(	2)
TYPE	M	MIXED-SHRUB	176.0000	8.8000	4.0079	16.0632	(	20)
TYPE	P	JUNIPER	257.0000	9.8846	4.0726	16.5862	(	26)
TYPE	S	SAGEBRUSH	660.0000	7.0968	3.5141	12.3492	(	93)

TOTAL CASES = 176

Appendix 3. Analysis comparing absolute cover of common species on the disturbed sites for each vegetation type. Cover values are expressed in percent.

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV1 ACMI
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			29.3420	.1667	1.3969	1.9515	(176)
TYPE	A	ASPEN	.0800	.0133	.0327	.0011	(6)
TYPE	C	CONIFER	1.3600	.1511	.3185	.1014	(9)
TYPE	G	GRASSLAND	23.8140	1.1907	4.0634	16.5110	(20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(2)
TYPE	M	MIXED-SHRUB	.7050	.0352	.1334	.0178	(20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(26)
TYPE	S	SAGEBRUSH	3.3830	.0364	.1752	.0307	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV2 AGCR
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			800.2400	4.5468	6.0157	36.1887	(176)
TYPE	A	ASPEN	26.0000	4.3333	4.6124	21.2747	(6)
TYPE	C	CONIFER	1.3820	.1536	.2577	.0664	(9)
TYPE	G	GRASSLAND	61.7150	3.0857	5.3306	28.4152	(20)
TYPE	H	SHADSCALE	1.5000	.7500	1.0607	1.1250	(2)
TYPE	M	MIXED-SHRUB	97.4500	4.8725	5.3809	28.9538	(20)
TYPE	P	JUNIPER	176.3500	6.7827	6.0092	36.1102	(26)
TYPE	S	SAGEBRUSH	435.8430	4.6865	6.4713	41.8783	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV3 AGDA
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			258.0100	1.4660	3.3249	11.0551	(	176)
TYPE	A	ASPEN	2.4000	.4000	.6197	.3840	(	6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(	9)
TYPE	G	GRASSLAND	53.2500	2.6625	4.1210	16.9829	(	20)
TYPE	H	SHADSCALE	1.5000	.7500	1.0607	1.1250	(	2)
TYPE	M	MIXED-SHRUB	53.9700	2.6985	4.9798	24.7982	(	20)
TYPE	P	JUNIPER	66.5300	2.5588	4.6312	21.4484	(	26)
TYPE	S	SAGEBRUSH	80.3600	.8641	2.2131	4.8979	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV4 AGEL
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			89.9500	.5111	2.2262	4.9559	(	176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(	6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(	9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	.0000	.0000	.0000	.0000	(	20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(	26)
TYPE	S	SAGEBRUSH	89.9500	.9672	2.9968	8.9810	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV5 AGIN
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			566.2220	3.2172	5.9741	35.6899	(	176)
TYPE	A	ASPEN	8.0000	1.3333	3.2660	10.6667	(	6)
TYPE	C	CONIFER	43.4820	4.8313	7.2541	52.6222	(	9)
TYPE	G	GRASSLAND	11.6000	.5800	1.7309	2.9961	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	47.8400	2.3920	4.2395	17.9738	(	20)
TYPE	P	JUNIPER	30.0400	1.1554	2.5398	6.4508	(	26)
TYPE	S	SAGEBRUSH	425.2600	4.5727	7.1568	51.2192	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV6 AGSM
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			412.6090	2.3444	4.1352	17.0996	(	176)
TYPE	A	ASPEN	8.7500	1.4583	1.8890	3.5684	(	6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(	9)
TYPE	G	GRASSLAND	71.8800	3.5940	4.3601	19.0109	(	20)
TYPE	H	SHADSCALE	1.6500	.8250	.9546	.9112	(	2)
TYPE	M	MIXED-SHRUB	55.4350	2.7717	4.8685	23.7024	(	20)
TYPE	P	JUNIPER	103.4000	3.9769	5.3434	28.5518	(	26)
TYPE	S	SAGEBRUSH	171.4940	1.8440	3.7038	13.7181	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV7 A6SP
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			4.1920	.0238	.1473	.0217	(176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(6)
TYPE	C	CONIFER	.7500	.0833	.2500	.0625	(9)
TYPE	G	GRASSLAND	.5170	.0258	.1003	.0101	(20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(2)
TYPE	M	MIXED-SHRUB	.0580	.0029	.0090	.0001	(20)
TYPE	P	JUNIPER	.5400	.0208	.1059	.0112	(26)
TYPE	S	SAGEBRUSH	2.3270	.0250	.1737	.0302	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV8 A6TRI
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			163.7240	.9302	3.4499	11.9015	(176)
TYPE	A	ASPEN	38.4700	6.4117	12.7237	161.8920	(6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(9)
TYPE	G	GRASSLAND	10.9000	.5450	2.2319	4.9813	(20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(2)
TYPE	M	MIXED-SHRUB	27.7800	1.3890	3.9091	15.2814	(20)
TYPE	P	JUNIPER	3.5000	.1346	.4808	.2312	(26)
TYPE	S	SAGEBRUSH	83.0740	.8933	2.6966	7.2715	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV9 AGTRY
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			128.8280	.7320	1.7435	3.0398	(	176)
TYPE	A	ASPEN	5.6000	.9333	2.2862	5.2267	(	6)
TYPE	C	CONIFER	10.8400	1.2044	2.2225	4.9393	(	9)
TYPE	G	GRASSLAND	26.3100	1.3155	2.6486	7.0150	(	20)
TYPE	H	SHADSCALE	.3000	.1500	.2121	.0450	(	2)
TYPE	M	MIXED-SHRUB	14.3930	.7196	1.7627	3.1071	(	20)
TYPE	P	JUNIPER	4.4450	.1710	.7835	.6138	(	26)
TYPE	S	SAGEBRUSH	66.9400	.7198	1.6174	2.6159	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV10 ARCA
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			1.7900	.0102	.0990	.0098	(	176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(	6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(	9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	.0200	.0010	.0045	.0000	(	20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(	26)
TYPE	S	SAGEBRUSH	1.7700	.0190	.1359	.0185	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV11 ARTR
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			144.3060	.8199	3.2674	10.6757	(	176)
TYPE	A	ASPEN	1.4700	.2450	.3890	.1513	(	6)
TYPE	C	CONIFER	.6900	.0767	.1300	.0169	(	9)
TYPE	G	GRASSLAND	5.3370	.2668	.8732	.7624	(	20)
TYPE	H	SHADSCALE	.0100	.0050	.0071	.0000	(	2)
TYPE	M	MIXED-SHRUB	51.0980	2.5549	7.0544	49.7652	(	20)
TYPE	P	JUNIPER	1.9370	.0745	.2251	.0507	(	26)
TYPE	S	SAGEBRUSH	83.7640	.9007	2.9789	8.8741	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV12 ASCI
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			6.4650	.0367	.1583	.0251	(	176)
TYPE	A	ASPEN	.4280	.0713	.1708	.0292	(	6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(	9)
TYPE	G	GRASSLAND	.7500	.0375	.1180	.0139	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	.5700	.0285	.1275	.0162	(	20)
TYPE	P	JUNIPER	1.6500	.0635	.2945	.0867	(	26)
TYPE	S	SAGEBRUSH	3.0670	.0330	.1257	.0158	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV13 ASTER
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			27.1950	.1545	1.0308	1.0626	(176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(6)
TYPE	C	CONIFER	10.0600	1.1178	2.2572	5.0948	(9)
TYPE	G	GRASSLAND	2.1000	.1050	.3375	.1139	(20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(2)
TYPE	M	MIXED-SHRUB	11.3400	.5670	2.5145	6.3229	(20)
TYPE	P	JUNIPER	.5200	.0200	.0883	.0078	(26)
TYPE	S	SAGEBRUSH	3.1750	.0341	.3110	.0967	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV14 ASTRA
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			4.8760	.0277	.1841	.0339	(176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(9)
TYPE	G	GRASSLAND	.1050	.0052	.0202	.0004	(20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(2)
TYPE	M	MIXED-SHRUB	1.8790	.0939	.4017	.1614	(20)
TYPE	P	JUNIPER	2.8650	.1102	.3160	.0999	(26)
TYPE	S	SAGEBRUSH	.0270	.0003	.0021	.0000	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV15 BRIN
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			259.7710	1.4760	3.6617	13.4081	(	176)
TYPE	A	ASPEN	14.1000	2.3500	4.8016	23.0550	(	6)
TYPE	C	CONIFER	37.3500	4.1500	3.8594	14.8950	(	9)
TYPE	G	GRASSLAND	7.5290	.3764	1.1981	1.4353	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	21.1910	1.0595	1.8720	3.5042	(	20)
TYPE	P	JUNIPER	.5750	.0221	.1059	.0112	(	26)
TYPE	S	SAGEBRUSH	179.0260	1.9250	4.4760	20.0348	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV16 BRMA
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			21.6100	.1228	.9419	.8872	(	176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(	6)
TYPE	C	CONIFER	2.2500	.2500	.5303	.2812	(	9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	11.2600	.5630	2.5155	6.3275	(	20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(	26)
TYPE	S	SAGEBRUSH	8.1000	.0871	.5499	.3024	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV17 CHNA
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			41.1910	.2340	1.2220	1.4933	(	176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(	6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(	9)
TYPE	G	GRASSLAND	2.2500	.1125	.5031	.2531	(	20)
TYPE	H	SHADSCALE	4.1500	2.0750	2.7224	7.4112	(	2)
TYPE	M	MIXED-SHRUB	3.2150	.1607	.6381	.4071	(	20)
TYPE	P	JUNIPER	1.8650	.0717	.2557	.0654	(	26)
TYPE	S	SAGEBRUSH	29.7110	.3195	1.5824	2.5041	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV18 CHVI
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			47.8960	.2721	2.4332	5.9205	(	176)
TYPE	A	ASPEN	1.4700	.2450	.3890	.1513	(	6)
TYPE	C	CONIFER	.0100	.0011	.0033	.0000	(	9)
TYPE	G	GRASSLAND	.0640	.0032	.0099	.0001	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	30.9380	1.5469	6.7002	44.8923	(	20)
TYPE	P	JUNIPER	1.0980	.0422	.2057	.0423	(	26)
TYPE	S	SAGEBRUSH	14.3160	.1539	1.2506	1.5640	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV19 DAGL
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			71.2800	.4050	2.4337	5.9230	(	176)
TYPE	A	ASPEN	.0800	.0133	.0327	.0011	(	6)
TYPE	C	CONIFER	41.7000	4.6333	8.3754	70.1474	(	9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	7.5000	.3750	1.1553	1.3346	(	20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(	26)
TYPE	S	SAGEBRUSH	22.0000	.2366	1.7371	3.0176	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV20 ERIOG
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			19.4530	.1105	.9616	.9246	(	176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(	6)
TYPE	C	CONIFER	.3000	.0333	.1000	.0100	(	9)
TYPE	G	GRASSLAND	6.0400	.3020	1.3412	1.7988	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	11.6100	.5805	2.5126	6.3133	(	20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(	26)
TYPE	S	SAGEBRUSH	1.5030	.0162	.1116	.0125	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV21 6IA6
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			3.7840	.0215	.1914	.0366	(	176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(	6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(	9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	1.8000	.0900	.4025	.1620	(	20)
TYPE	P	JUNIPER	.0900	.0035	.0177	.0003	(	26)
TYPE	S	SAGEBRUSH	1.8940	.0204	.1867	.0348	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV22 HOJU
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			41.8820	.2380	1.8737	3.5106	(	176)
TYPE	A	ASPEN	.0080	.0013	.0033	.0000	(	6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(	9)
TYPE	G	GRASSLAND	7.0290	.3514	1.3415	1.7997	(	20)
TYPE	H	SHADSCALE	.3000	.1500	.2121	.0450	(	2)
TYPE	M	MIXED-SHRUB	1.2230	.0611	.2681	.0719	(	20)
TYPE	P	JUNIPER	2.9550	.1137	.3493	.1220	(	26)
TYPE	S	SAGEBRUSH	30.3670	.3265	2.4953	6.2264	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV23 LOPE
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			5.7620	.0327	.2289	.0524	(176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(6)
TYPE	C	CONIFER	.3000	.0333	.1000	.0100	(9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(2)
TYPE	M	MIXED-SHRUB	.0000	.0000	.0000	.0000	(20)
TYPE	P	JUNIPER	1.5000	.0577	.2942	.0865	(26)
TYPE	S	SAGEBRUSH	3.9620	.0426	.2728	.0744	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV24 LUCA
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			14.5970	.0829	.5986	.3583	(176)
TYPE	A	ASPEN	.6000	.1000	.2449	.0600	(6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(20)
TYPE	H	SHADSCALE	1.5000	.7500	1.0607	1.1250	(2)
TYPE	M	MIXED-SHRUB	.0340	.0017	.0076	.0001	(20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(26)
TYPE	S	SAGEBRUSH	12.4630	.1340	.8051	.6482	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE SPPCOV25 MEOF
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			27.0050	.1534	.7599	.5774	(	176)
TYPE	A	ASPEN	2.4000	.4000	.9798	.9600	(	6)
TYPE	C	CONIFER	17.9320	1.9924	2.6675	7.1153	(	9)
TYPE	G	GRASSLAND	1.0850	.0542	.2345	.0550	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	1.2340	.0617	.1843	.0339	(	20)
TYPE	P	JUNIPER	.3450	.0133	.0591	.0035	(	26)
TYPE	S	SAGEBRUSH	4.0090	.0431	.2257	.0509	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE SPPCOV26 MESA
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			111.9780	.6362	2.0536	4.2174	(	176)
TYPE	A	ASPEN	2.1000	.3500	.8573	.7350	(	6)
TYPE	C	CONIFER	4.8000	.5333	1.2166	1.4800	(	9)
TYPE	G	GRASSLAND	3.6900	.1845	.3545	.1256	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	21.0890	1.0544	2.3208	5.3862	(	20)
TYPE	P	JUNIPER	1.8350	.0706	.2974	.0885	(	26)
TYPE	S	SAGEBRUSH	78.4640	.8437	2.5416	6.4598	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV27 ONVI
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			14.8050	.0841	.4940	.2440	(176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(6)
TYPE	C	CONIFER	.7200	.0800	.2400	.0576	(9)
TYPE	G	GRASSLAND	7.9650	.3982	1.2493	1.5608	(20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(2)
TYPE	M	MIXED-SHRUB	.0500	.0025	.0079	.0001	(20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(26)
TYPE	S	SAGEBRUSH	6.0700	.0653	.3331	.1110	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV28 ORHY
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			19.8140	.1126	1.0633	1.1306	(176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(9)
TYPE	G	GRASSLAND	14.2070	.7103	3.1282	9.7859	(20)
TYPE	H	SHADSCALE	.1600	.0800	.0990	.0098	(2)
TYPE	M	MIXED-SHRUB	.0310	.0015	.0049	.0000	(20)
TYPE	P	JUNIPER	2.1100	.0812	.2571	.0661	(26)
TYPE	S	SAGEBRUSH	3.3060	.0355	.1511	.0228	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV29 PESP
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			3.8400	.0218	.2285	.0522	(	176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(	6)
TYPE	C	CONIFER	.3130	.0348	.0995	.0099	(	9)
TYPE	G	GRASSLAND	.0150	.0007	.0034	.0000	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	.3930	.0196	.0804	.0065	(	20)
TYPE	P	JUNIPER	.0300	.0012	.0059	.0000	(	26)
TYPE	S	SAGEBRUSH	3.0890	.0332	.3110	.0967	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV30 PHPR
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			56.2460	.3196	1.6163	2.6126	(	176)
TYPE	A	ASPEN	2.4000	.4000	.9798	.9600	(	6)
TYPE	C	CONIFER	12.4320	1.3813	2.7048	7.3158	(	9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	33.8500	1.6925	3.9685	15.7490	(	20)
TYPE	P	JUNIPER	.0340	.0013	.0067	.0000	(	26)
TYPE	S	SAGEBRUSH	7.5300	.0810	.6306	.3976	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV31 POPR
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			49.0260	.2786	1.6124	2.5998	(	176)
TYPE	A	ASPEN	.0800	.0133	.0327	.0011	(	6)
TYPE	C	CONIFER	5.5500	.6167	.7810	.6100	(	9)
TYPE	G	GRASSLAND	22.6500	1.1325	4.0867	16.7009	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	2.4000	.1200	.4175	.1743	(	20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(	26)
TYPE	S	SAGEBRUSH	18.3460	.1973	1.0941	1.1970	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE OIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV32 ROWO
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			.6290	.0036	.0431	.0019	(	176)
TYPE	A	ASPEN	.0140	.0023	.0057	.0000	(	6)
TYPE	C	CONIFER	.0400	.0044	.0133	.0002	(	9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	.5750	.0287	.1274	.0162	(	20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(	26)
TYPE	S	SAGEBRUSH	.0000	.0000	.0000	.0000	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV33 SAMI
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			2.6320	.0150	.1237	.0153	(176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(9)
TYPE	G	GRASSLAND	.0370	.0018	.0078	.0001	(20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(2)
TYPE	M	MIXED-SHRUB	.0000	.0000	.0000	.0000	(20)
TYPE	P	JUNIPER	1.5000	.0577	.2942	.0865	(26)
TYPE	S	SAGEBRUSH	1.0950	.0118	.0702	.0049	(93)

TOTAL CASES = 176

SPSS ' 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV34 SIHY
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			2.3830	.0135	.0797	.0064	(176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(6)
TYPE	C	CONIFER	.3900	.0433	.1007	.0101	(9)
TYPE	G	GRASSLAND	.0010	.0000	.0002	.0000	(20)
TYPE	H	SHADSCALE	.1500	.0750	.1061	.0112	(2)
TYPE	M	MIXED-SHRUB	.0250	.0012	.0056	.0000	(20)
TYPE	P	JUNIPER	.0590	.0023	.0066	.0000	(26)
TYPE	S	SAGEBRUSH	1.7580	.0189	.1036	.0107	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV35 SPGR
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			.8200	.0047	.0455	.0021	(	176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(	6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(	9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	.0710	.0035	.0110	.0001	(	20)
TYPE	P	JUNIPER	.0900	.0035	.0099	.0001	(	26)
TYPE	S	SAGEBRUSH	.6590	.0071	.0623	.0039	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV36 STCO
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE		N
FOR ENTIRE POPULATION			20.9050	.1188	.9060	.8209	(	176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(	6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(	9)
TYPE	G	GRASSLAND	1.5250	.0762	.3017	.0910	(	20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(	2)
TYPE	M	MIXED-SHRUB	13.0500	.6525	2.5266	6.3835	(	20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(	26)
TYPE	S	SAGEBRUSH	6.3300	.0681	.3909	.1528	(	93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV37 SYOR
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			.7970	.0045	.0286	.0008	(176)
TYPE	A	ASPEN	.0510	.0085	.0116	.0001	(6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(9)
TYPE	G	GRASSLAND	.0000	.0000	.0000	.0000	(20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(2)
TYPE	M	MIXED-SHRUB	.4770	.0238	.0800	.0064	(20)
TYPE	P	JUNIPER	.1840	.0071	.0196	.0004	(26)
TYPE	S	SAGEBRUSH	.0850	.0009	.0048	.0000	(93)

TOTAL CASES = 176

SPSS 10/23/84

FILE DIASPSS (CREATION DATE = 10/16/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE SPPCOV38 TRIFOL
BROKEN DOWN BY TYPE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			2.1560	.0122	.1147	.0132	(176)
TYPE	A	ASPEN	.0000	.0000	.0000	.0000	(6)
TYPE	C	CONIFER	.0000	.0000	.0000	.0000	(9)
TYPE	G	GRASSLAND	.0350	.0017	.0078	.0001	(20)
TYPE	H	SHADSCALE	.0000	.0000	.0000	.0000	(2)
TYPE	M	MIXED-SHRUB	.0000	.0000	.0000	.0000	(20)
TYPE	P	JUNIPER	.0000	.0000	.0000	.0000	(26)
TYPE	S	SAGEBRUSH	2.1210	.0228	.1574	.0248	(93)

TOTAL CASES = 176

APPENDIX 4. Table of the data that was used for analysis in the field assessment report. See descriptions at the end of this appendix to interprete the letter codes.

A	BC	D	EF	GHIJ	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	12	4	20	331	1SBW18N11	111112	9045	1201842	352520	1441		42	2	2			3	
1	22	4	20	331	1SBW18N11	111112	9048	901842	353040	0252	4	2		2			4	
1	32	4	20	331	1SBW18N11	111112	9052	501842	504545	5		4	4		3		3	
1	42	4	20	331	1SBW18N11	111111	0	1	1001842	656010	25	3	4				23	
1	52	4	20	331	1SBW18N11	11223	227037		1001842	201350	30112	4	33	11			3	
1	62	4	20	331	1SBW18N11	113342	055		601842	352530	13424		2	42	22			
1	72	4	20	331	1SBW18N11	11232	212534		601842	10	915	570		43	12		4	
1	82	4	20	331	1SBW18N11	111111	90	1	3001842	202015	65	2	2	44			2	
1	92	4	20	331	1SBW18N11	111111	90	4	6001842	20	530	50		44			2	
2	12	4	70	361	0SBW19N	1111	165	4	5003533	1	1	1089						
3	12	5	00	333	1SBW18N 1	1	1111	90	5	501842	201230	502			2	4	3	24
3	22	5	00	333	1SBW18N 1	1	121	127015		503533	7	4	520681		34	2	1	
3	32	5	00	333	1SBW18N 1	1	1122	010		2503355	3510	5	555		1	2	1	
4	12	5	00	332	0SBW19N	1	1121	3014		3003533	10	1401040		3	3	3		
5	12	4	40	331	0SBW18N	1	2212	0	9	503533	301010	5451	3	3	3	12		
6	12	4	80	362	2GBW18N	111111	60	5		503533	3025	3	265		44			
7	12	1	80	381	1PPW18N	1	335410570			65	515R15	0153030						
7	22	1	80	381	2PPW18N	1	1111	90	1	153533620	5	175	4	4	2	4	2	
8	12	1	80	383	2PBW18N1	1	1121	135	5	150102562019		52055	4		3	1	2	
9	12	1	03	31	1SBW18N1 1	1	11112	180	8	1503533	2014	5	174			43	2	
10	12	3	10	331	1SWW19N	1	1112	270	8	3503533	201020	1591			2	34	11	
11	12	3	60	383	1MBW19N	1	233	218030		501842	15	515	565			4		
11	22	3	60	383	1MBW19N	1	112	218032		501025	201975	2	31			34	2	
11	32	3	60	513	1ABW19N	1	212	227545		1003355	151481	1	3			44	2	3
12	12	4	20	361	1GBW18N11	1	123	227027		150184263015		11059	42	142	3			
12	22	4	20	361	1GBW18N11	1	322	117532		601842610	5	16425	4		2	3		
12	32	4	20	361	1GBW18N11	1	334	427560		5018426	1	1105930	4		2	3		
13	12	3	00	382	4PPW18N1		1122	250	9	501025	2018	33047	43		42	2	2	1
14	12	4	03	32	2SBW18N11	11	1111	260	5	753533620	7	51560	42		2			
15	12	3	50	383	1PPW18N 1	1	211	117038		503533	101075	510			34	3		
16	12	2	20	331	2SPW18N 1	1111	132175		7	1503533	1512	3	181		4	3		
17	12	1	70	381	2PBW18N1	1	233	210020		401025	1514	32062	4		3			
18	12	3	30	511	4ABW17N 1		343	235027		303533	3029	3	265	4		3	2	2
18	22	3	30	331	4SBW17N 1		122	131013		303533	3534	2	360	4		32	2	2
18	32	3	30	511	4ABW17N 1		3443	520		303533	2020	1	475	4	4		2	
19	12	3	30	381	2MPW17N 1		334	329533		401842	3030	1	465	44	3			
19	22	3	30	381	2MPW17N 1		345	230543		303533	2323	2	174	3	4		1	
20	12	3	20	331	2SPW17N		11555	512080		156020	1	1	0	198		44	2	
20	22	3	20	331	2SPW17N		111111	0	0	5027156	4	4	15045	43	4		2	
20	32	3	20	331	2SPW17N		112	342	12516	303533	3027	3	265	43	23		2	
20	42	3	20	331	2SPW17N		114	452	13027	303533		7	5	1	485	43	4	3
21	12	3	80	331	5SBW17N 1		111	32011		1203533	4544	3	151	4		2	2	4
21	22	3	80	331	5SBW17N 1		1222	010		303533	404025	134	4		3	3	2	1
22	12	3	40	331	4SPW17N 1	1	334	332525		303533	3029	5	164	4		3	3	
23	12	3	10	331	4SBW17N 1		1333	218519		801842	252515	357	4		43			
24	12	2	70	331	3SBW17N 1	1	222	216014		1001842	2515	1	569	2	4		1	
24	22	2	70	331	3SBW17N 1	1	344	214025		201025	2019	5	570	3	4		2	1
25	12	3	50	381	4MPW17N 1			245	217020		153533	3030	5	560	41	2	1	
25	22	3	50	381	4MPW17N 1			234	234023		253533	2525	4	566	42	21		
26	12	3	10	381	2PBW17N 1			345	413518		503533	303020		149	41	33		

A	BC	D	EF	GHIJ	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	12	4	20	331	1SBW18N11	111112	9045	1201842	352520	1441		42	2	2			3	
1	22	4	20	331	1SBW18N11	111112	9048	901842	353040	0252	4	2		2			4	
1	32	4	20	331	1SBW18N11	111112	9052	501842	504545	5		4	4		3		3	
1	42	4	20	331	1SBW18N11	111111	0	1	1001842	656010	25	3	4				23	
1	52	4	20	331	1SBW18N11	11223	227037		1001842	201350	30112	4	33	11			3	
1	62	4	20	331	1SBW18N11	113342	055		601842	352530	13424		2	42	22			
1	72	4	20	331	1SBW18N11	11232	212534		601842	10	915	570		43	12		4	
1	82	4	20	331	1SBW18N11	111111	90	1	3001842	202015	65	2	2	44			2	
1	92	4	20	331	1SBW18N11	111111	90	4	6001842	20	530	50		44			2	
2	12	4	70	361	0SBW19N	1111	165	4	5003533	1	1	1089						
3	12	5	00	333	1SBW18N 1	1	1111	90	5	501842	201230	502			2	4	3	24
3	22	5	00	333	1SBW18N 1	1	121	127015		503533	7	4	520681		34	2	1	
3	32	5	00	333	1SBW18N 1	1	1122	010		2503355	3510	5	555		1	2	1	
4	12	5	00	332	0SBW19N	1	1121	3014		3003533	10	1401040		3	3	3		
5	12	4	40	331	0SBW18N	1	2212	0	9	503533	301010	5451	3	3	3	12		
6	12	4	80	362	2GBW18N	111111	60	5		503533	3025	3	265		44			
7	12	1	80	381	1PPW18N	1	335410570			65	515R15	0153030						
7	22	1	80	381	2PPW18N	1	1111	90	1	153533620	5	175	4	4	2	4	2	
8	12	1	80	383	2PBW18N1	1	1121	135	5	150102562019		52055	4		3	1	2	
9	12	1	03	31	1SBW18N1 1	1	11112	180	8	1503533	2014	5	174			43	2	
10	12	3	10	331	1SWW19N	1	1112	270	8	3503533	201020	1591			2	34	11	
11	12	3	60	383	1MBW19N	1	233	218030		501842	15	515	565			4		
11	22	3	60	383	1MBW19N	1	112	218032		501025	201975	2	31			34	2	
11	32	3	60	513	1ABW19N	1	212	227545		1003355	151481	1	3			44	2	3
12	12	4	20	361	1GBW18N11	1	123	227027		150184263015		11059	42	142	3			
12	22	4	20	361	1GBW18N11	1	322	117532		601842610	5	16425	4		2	3		
12	32	4	20	361	1GBW18N11	1	334	427560		5018426	1	1105930	4		2	3		
13	12	3	00	382	4PPW18N1		1122	250	9	501025	2018	33047	43		42	2	2	1
14	12	4	03	32	2SBW18N11	11	1111	260	5	753533620	7	51560	42		2			
15	12	3	50	383	1PPW18N 1	1	211	117038		503533	101075	510			34	3		
16	12	2	20	331	2SPW18N 1	1111	132175		7	1503533	1512	3	181		4	3		
17	12	1	70	381	2PBW18N1	1	233	210020		401025	1514	32062	4		3			
18	12	3	30	511	4ABW17N 1		343	235027		303533	3029	3	265	4		3	2	2
18	22	3	30	331	4SBW17N 1		122	131013		303533	3534	2	360	4		32	2	2
18	32	3	30	511	4ABW17N 1		3443	520		303533	2020	1	475	4	4		2	
19	12	3	30	381	2MPW17N 1		334	329533		401842	3030	1	465	44	3			
19	22	3	30	381	2MPW17N 1		345	230543		303533	2323	2	174	3	4		1	
20	12	3	20	331	2SPW17N		11555	512080		156020	1	1	0	198		44	2	
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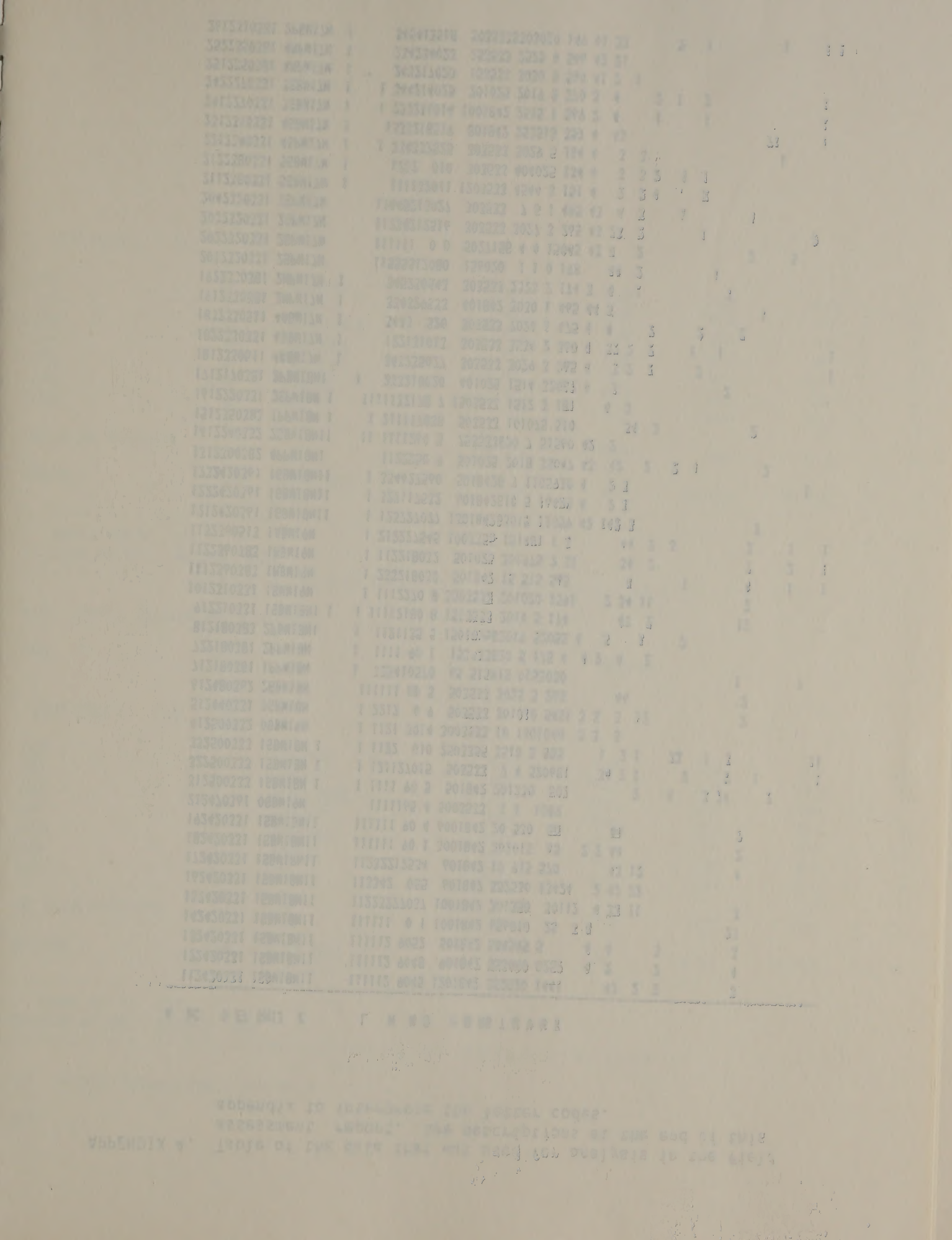

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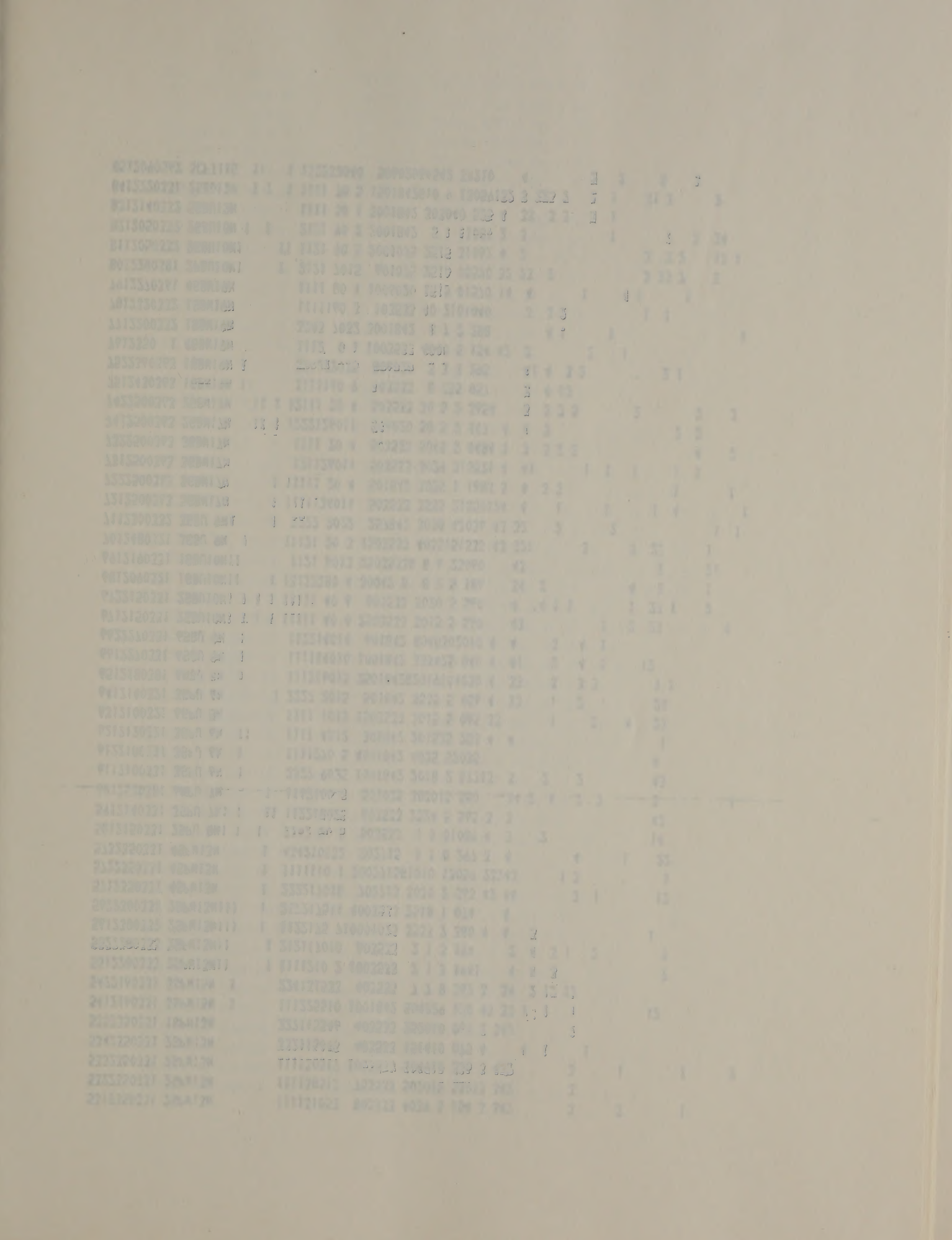

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	columns	variable
A	1-2	Site number
B	3	Subsite number
C	4-7	Elevation (m)
D	8-9	Annual precipitation (cm)
E	10	Type of disturbance 1=pad 2=road 3=pipeline
F	11-12	Age of recamation
G	13	Vegetation type, A=aspen, C=conifer, S=sagebrush, G=grassland, P=pinyon-Juniper, M=mixed shrub, H=shadscale.
H	14	Land ownership, P=private, B=BLM, F=Forest Service, W=State of Wyoming
I	15	Location (state), W=Wyoming, U=Utah, I=Idaho
J	16-18	Township
K	19-27	Common weeds, 1=present, blank=absent, column (19)BRTE, (20) CHAL, (21) CIAR, (22)CANU, (23) HYNI, (24) HAGL, (25) SAKA, (26) POAR, (27) THAR
L	28-31	Erosion categories, values range from 1-5, see figure 3 for explanation, (28) litter movement, (29) pedastalling (30) rills, (31) gullies
M	32-34	Aspect
N	35-36	Slope (%)
O	37-40	Slope length
P	41-42	Clay in the soil (%)
Q	43-44	Silt content of the soil (%)

Column	Variable
A 1-2	Site number
B 3	Subsite number
C 4-7	Elevation (m)
D 8-9	Annual precipitation (cm)
E 10	Type of disturbance
F 11-12	Age of vegetation
G 13	Vegetation type, A=aspen, C=woodland, S=sagebrush, G=grass/forb
	P=pinyon-juniper, M=mixed shrub, B=shadscale.
	W=state of Wyoming
H 14	Land ownership, P=private, BLM, F=Forest Service,
I 15	Location (state), W=Wyoming, U=Utah, I=Idaho
J 16-18	Township
K 19-27	Common weeds, 1=present, blank=absent, column (19)BROTE,
	(20) CHAL, (21) CIAR, (22)CHNU, (23) HYNI, (24) MOCU,
	(25) SAKA, (26) TOAP, (27) THAR
L 28-33	Erosion category, values range from 1-5, see figure 1
	for explanation, (29) litter movement, (29) pedestalling
	(30) rills, (31) gullies
M 32-34	Aspect
N 35-36	Slope (%)
O 37-40	Slope length
P 41-42	Clay in the soil (%)
Q 43-44	Silt content of the soil (%)

R	45	Soil description prefix c=cobbly, g=gravelly, r=rocky
S	46-47	Total cover (%)
T	48-49	Perennial cover (%)
U	50-51	Litter cover (%)
V	52-53	Rock cover (%)
W	54-55	Bare Ground (%)
X	56-93	Species that were found in the sites sampled including a rating of their relative abundance, 1=rare, 2=uncommon, 3=common, 4=abundant, species occur in the following order

56 ACMI	75 ERIOG
57 AGCR	76 GIAG
58 AGDA	77 HOJU
59 AGEL	78 LOPE
60 AGIN	79 LUCA
61 AGSM	80 MEOF
62 AGSP	81 MESA
63 AGTRI	82 ONVI
64 AGTRY	83 ORHY
65 ARCA	84 PESP
66 ARTR	85 PHPR
67 ASCI	86 POPR
68 ASTER	87 ROWO
69 ASTRA	88 SAMI
70 BRIN	89 SIHY
71 BRMA	90 SPGR
72 CHNA	91 STCO
73 CHVI	92 SYOR
74 DAGL	93 TRIFOL

APPENDIX 5. Analysis of variance comparing the production plant sites (Chevron's Carter Creek and Amoco's Anshutz Ranch) with all other sites for total cover, perennial cover, litter, rock, bare ground, and erosion condition classification.

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE TOTCOVER TOTAL COVER
BROKEN DOWN BY NPI

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			4550.0000	25.8523	16.6140	276.0238	(176)
NPI	0.	OTHER SITES	3655.0000	23.8889	15.5053	240.4152	(153)
NPI	1.	PLANT SITES	895.0000	38.9130	18.1507	329.4486	(23)

TOTAL CASES = 176

CRITERION VARIABLE TOTCOVER

---------- ANALYSIS OF VARIANCE ----------

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
NPI	0.	OTHER SITES	3655.0000	23.8889	15.5053	36543.1111	(153)
NPI	1.	PLANT SITES	895.0000	38.9130	18.1507	7247.8261	(23)
	WITHIN GROUPS TOTAL		4550.0000	25.8523	15.8642	43790.9372	(176)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	4513.222	1	4513.222	17.933	.0000
WITHIN GROUPS	43790.937	174	251.672		

ETA = .3057 ETA SQUARED = .0934

FILE DISKFREE (CREATION DATE = 10/23/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE PERCOVER PERENNIAL COVER
BROKEN DOWN BY NPI

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			3859.0000	21.9261	17.1388	293.7774	(176)
NPI	0.	OTHER SITES	3076.0000	20.1046	16.0198	256.6377	(153)
NPI	1.	PLANT SITES	783.0000	34.0435	19.6688	386.8617	(23)

TOTAL CASES = 176

CRITERION VARIABLE PERCOVER

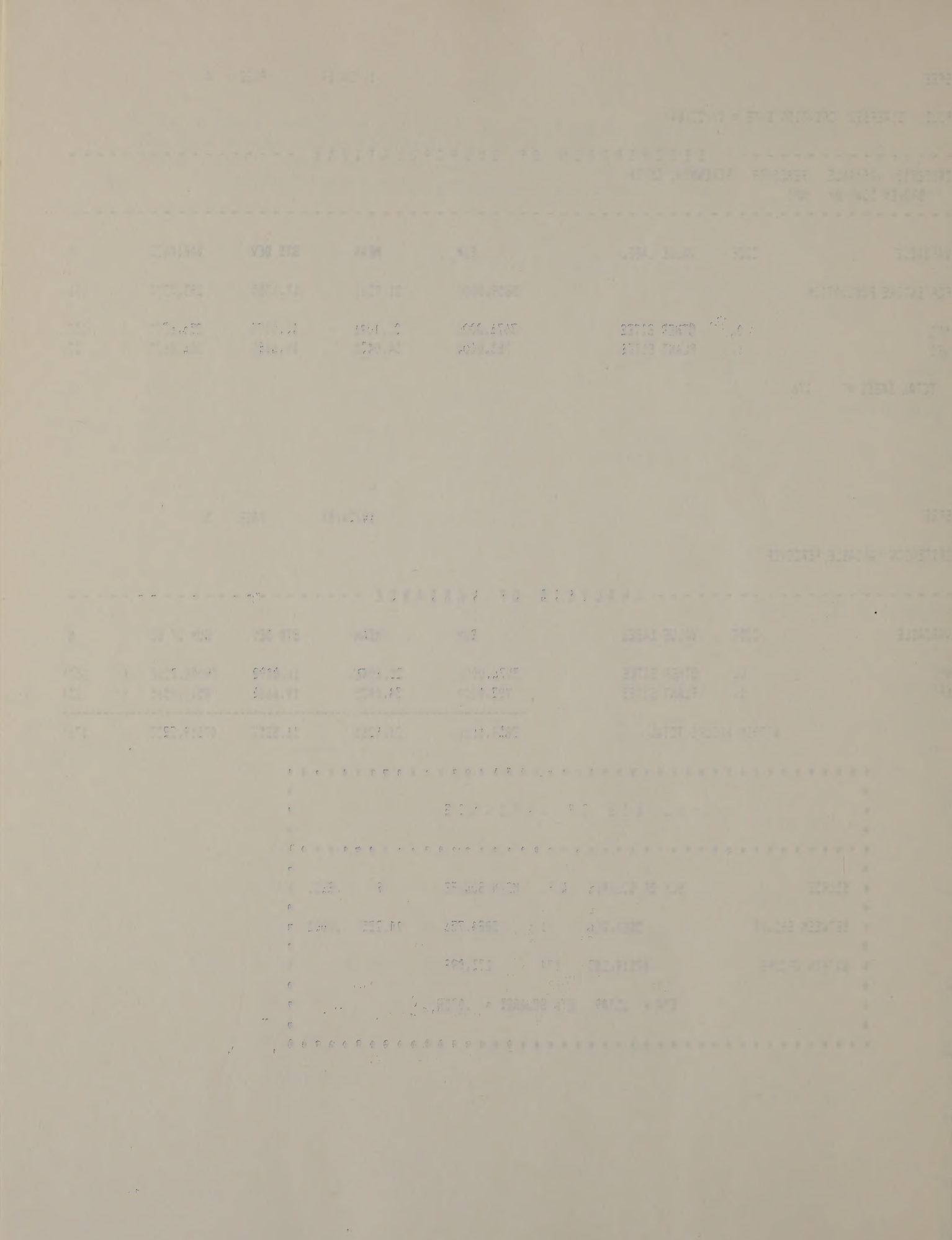
---------- ANALYSIS OF VARIANCE ----------

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
NPI	0.	OTHER SITES	3076.0000	20.1046	16.0198	39008.3046	(153)
NPI	1.	PLANT SITES	783.0000	34.0435	19.6688	8510.9565	(23)
	WITHIN GROUPS TOTAL		3859.0000	21.9261	16.5257	47519.2830	(176)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	3884.756	1	3884.756	14.225	.0002
WITHIN GROUPS	47519.283	174	273.099		

ETA = .2749 ETA SQUARED = .0756



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DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE LITTER
BROKEN DOWN BY NPI

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			1789.0000	10.1591	13.8175	190.9231	(176)
NPI	0.	OTHER SITES	1358.0000	8.8758	13.3458	178.1095	(153)
NPI	1.	PLANT SITES	430.0000	18.6957	14.1596	200.4941	(23)

TOTAL CASES = 176

CRITERION VARIABLE LITTER

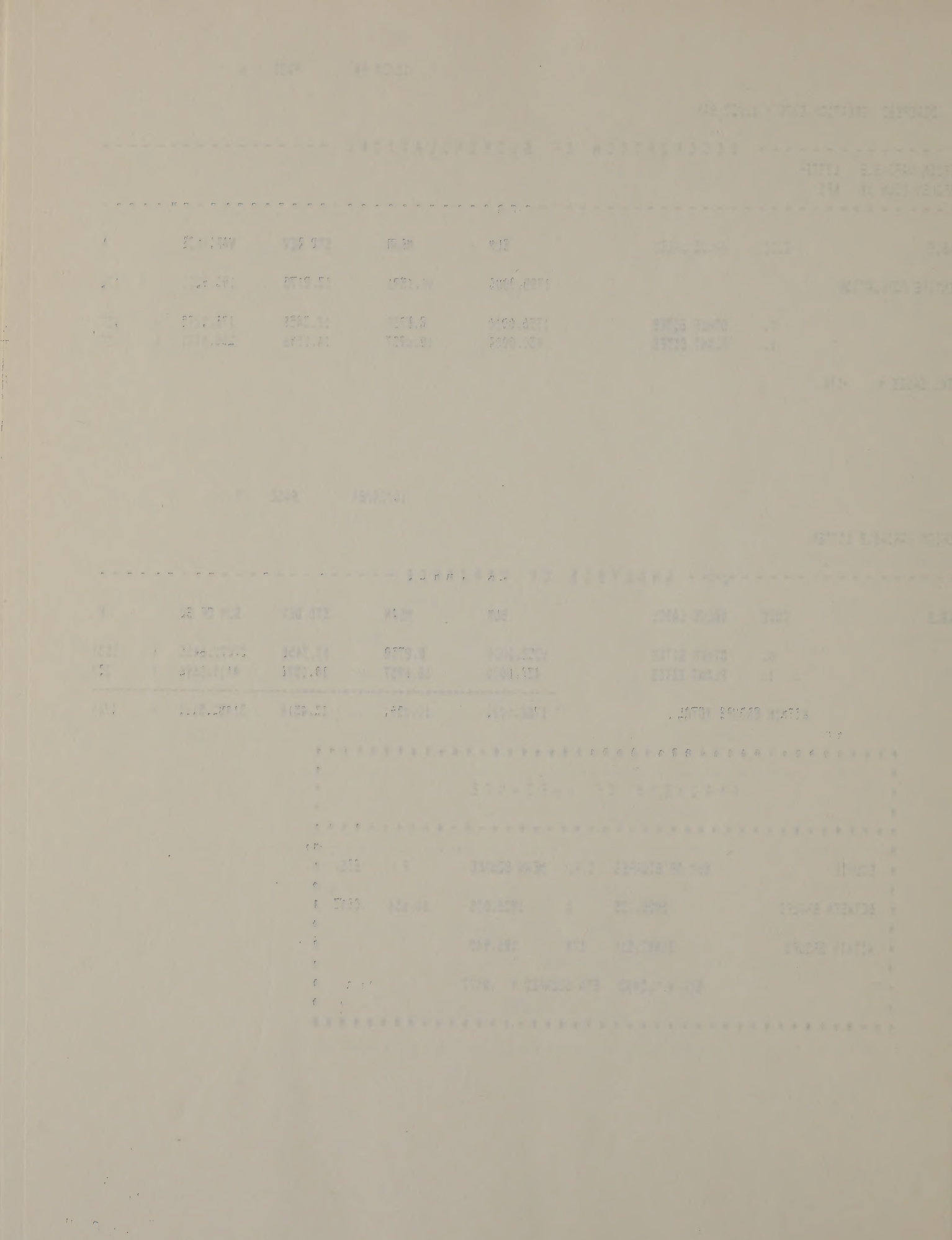
ANALYSIS OF VARIANCE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
NPI	0.	OTHER SITES	1358.0000	8.8758	13.3458	27072.6405	(153)
NPI	1.	PLANT SITES	430.0000	18.6957	14.1596	4410.8696	(23)
	WITHIN GROUPS TOTAL		1788.0000	10.1591	13.4514	31483.5101	(176)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	1928.035	1	1928.035	10.656	.0013
WITHIN GROUPS	31483.510	174	180.940		

ETA = .2402 ETA SQUARED = .0577



FILE DIABASES (CREATION DATE = 10/23/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE ROCK
BROKEN DOWN BY NPI

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			1868.0000	10.6136	16.3654	267.8270	(176)
NPI	0.	OTHER SITES	1824.0000	11.9216	17.1601	294.4675	(153)
NPI	1.	PLANT SITES	44.0000	1.9130	2.2139	4.9012	(23)

TOTAL CASES = 176

CRITERION VARIABLE ROCK

---------- ANALYSIS OF VARIANCE ----------

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
NPI	0.	OTHER SITES	1824.0000	11.9216	17.1601	44759.0588	(153)
NPI	1.	PLANT SITES	44.0000	1.9130	2.2139	107.8261	(23)
	WITHIN GROUPS TOTAL		1868.0000	10.6136	16.0579	44866.8849	(176)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	2002.842	1	2002.842	7.767	.0059
WITHIN GROUPS	44866.885	174	257.856		

ETA = .2067 ETA SQUARED = .0427

FILE DISPERSD (CREATION DATE = 10/23/84)

---------- DESCRIPTION OF SUBPOPULATIONS ----------

CRITERION VARIABLE BARE BARE GROUND
BROKEN DOWN BY NPI

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			9384.0000	53.3182	24.3379	592.3325	(176)
NPI	0.	OTHER SITES	8452.0000	55.2418	24.5909	604.7109	(153)
NPI	1.	PLANT SITES	932.0000	40.5217	18.3523	336.8067	(23)

TOTAL CASES = 176

CRITERION VARIABLE BARE

---------- ANALYSIS OF VARIANCE ----------

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
NPI	0.	OTHER SITES	8452.0000	55.2418	24.5909	91916.0523	(153)
NPI	1.	PLANT SITES	932.0000	40.5217	18.3523	7409.7391	(23)
	WITHIN GROUPS TOTAL		9384.0000	53.3182	23.8922	99325.7914	(176)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	4332.390	1	4332.390	7.590	.0065
WITHIN GROUPS	99325.791	174	570.838		

ETA = .2044 ETA SQUARED = .0418

FILE DIFFFEE2 (CREATION DATE = 10/23/84)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE TOTEEF EROSION CONDITION CLASSIFICATION
BROKEN DOWN BY NPI

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			1377.0000	7.8239	3.9319	15.4602	(176)
NPI	0.	OTHER SITES	1243.0000	8.1242	4.0414	16.3332	(153)
NPI	1.	PLANT SITES	134.0000	5.8261	2.3091	5.3320	(23)

TOTAL CASES = 176

CRITERION VARIABLE TOTEEF

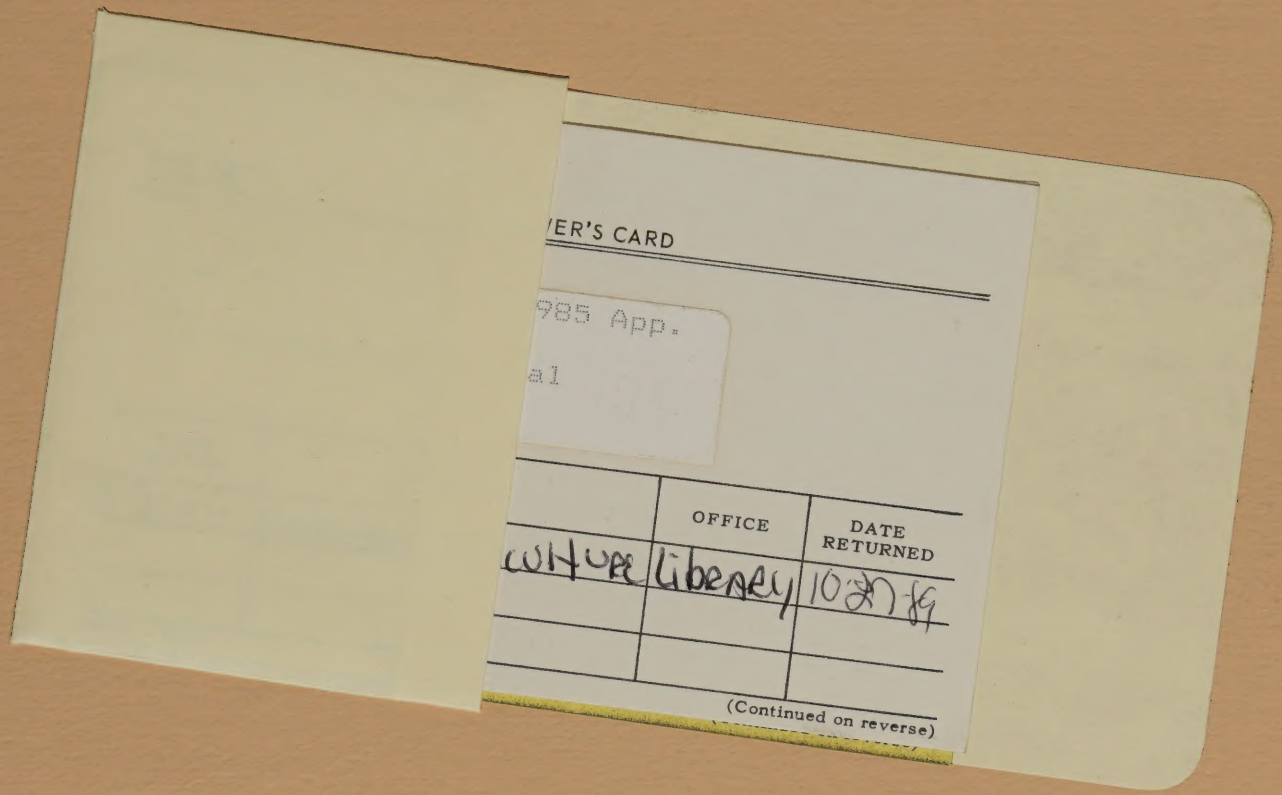
ANALYSIS OF VARIANCE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
NPI	0.	OTHER SITES	1243.0000	8.1242	4.0414	2482.6405	(153)
NPI	1.	PLANT SITES	134.0000	5.8261	2.3091	117.3043	(23)
	WITHIN GROUPS TOTAL		1377.0000	7.8239	3.8655	2599.9449	(176)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	105.595	1	105.595	7.067	.0086
WITHIN GROUPS	2599.945	174	14.942		

ETA = .1976 ETA SQUARED = .0390



ER'S CARD

985 App.

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	OFFICE	DATE RETURNED
cultural	Library	10-20-89

(Continued on reverse)